THE SCIENTIFIC MONTHLY

THE SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

VOLUME XXVII
JULY TO DECEMBER

NEW YORK
THE SCIENCE PRESS
1928

THE SCIENCE PRESS PRINTING COMPANY
LANCASTER, PA.

THE SCIENTIFIC MONTHLY

JULY, 1928

BASAL METABOLISM: THE MODERN MEASURE OF VITAL ACTIVITY[1]

By Dr. FRANCIS G. BENEDICT
DIRECTOR, NUTRITION LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

THE search of the ancient philosophers for the philosopher's stone or the elixir of life has been fruitless down through the centuries. If, instead of searching for the elixir of life, these men had sought an explanation of life processes, they would have made much greater progress, for in the past hundred years the elaborate studies which have been made in biophysics and biochemistry have explained the mechanistic features of life reasonably clearly. Thus, although the philosopher's stone remains unfound, life has been bettered and prolonged by the fundamental knowledge gained regarding its chemistry and physics.

The early investigators were not wholly indifferent to the importance of knowing what happens in the body during the processes of life, however. As early as the third century, B. C., Erasistratus made observations upon the insensible perspiration of hens and other fowls. That is, he made crude measurements of their loss in body weight and the weights of their food and excreta. At about the time when our Pilgrim fathers were landing in America, Sanctorius, of Padua, conceived the idea of weighing himself from hour to hour upon a special balance, thus being the first to obtain a quantitative measurement of the loss in body weight which is going on continuously in all living beings, with periodic gains due to food and drink. His investigations of the insensible perspiration with this crude method covered over thirty years. As a result of his findings he published a curious book of aphorisms, the greater number of which are wholly speculative but a few of which indicate that he had obtained marvelously clear conceptions of certain vital processes. For instance, he found that the loss in body weight is greatest when one is awake and has had food and that the larger person has the larger loss, findings which conform wholly to our present-day notions.

Sanctorius was followed by other investigators, but there was practically no scientific outcome from these long, tedious researches, and the study of the invisible loss in body weight remained dormant from his time until about 1900, when it was taken up again by Professor Warren P. Lombard, of Ann Arbor. Professor Lombard devised an extraordinarily accurate balance for this purpose and laid the foundations for the more recent work by the Nutrition Laboratory, in which the loss in body weight from hour to hour and, indeed, almost from minute to minute has been studied.

[1] Address delivered at the Carnegie Institution of Washington, Washington, D. C., April 18, 1928.

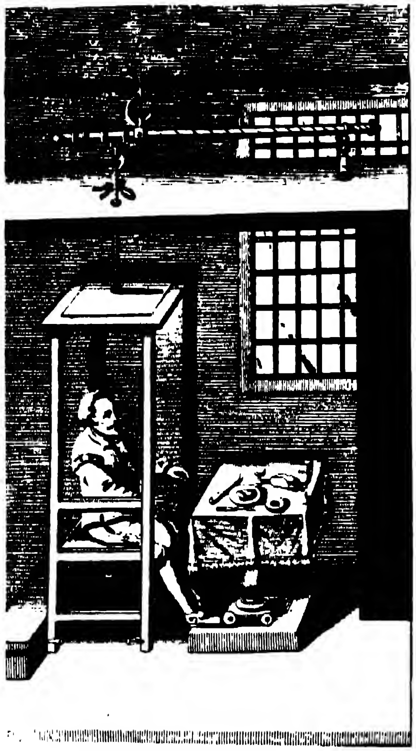


FIG. 1. SANCTORIUS OF PADUA DETERMINING HIS INSENSIBLE LOSS IN BODY WEIGHT.

This invisible loss in body weight, due chiefly to the loss of water vapor from the lungs and skin, has been found to be closely related to the main factors of life processes. For our first knowledge of the quantitative relations of these factors we are indebted to the great French savant, Lavoisier, who, nearly one hundred and fifty years ago, studied the chemistry of respiration with a technique marvelously in advance of anything conceived prior to his time and approximating with singular closeness much of the present-day technique. Lavoisier was the first to point out that all life processes are accompanied by the production of carbon dioxide and the absorption of oxygen by the lungs and the liberation of heat from the body. His measurements of the lung gases of man and his measurements of the heat actually given off by small animals represent the first steps in the acquisition of knowledge regarding human and animal metabolism, knowledge upon which our modern conception of nutrition is based.

A century of intense effort followed the unfortunate death of Lavoisier, and culminated in the classic experiments of Rubner with the dog and Atwater with humans. In these experiments a calorimeter was employed, an apparatus which, as the name implies, measures directly the heat given off from the body and, provided it is a respiration calorimeter, measures also the carbon-dioxide excretion and the oxygen absorption of the lungs. The experiments by Atwater with the respiration calorimeter at Wesleyan University in Middletown, Connecticut, showed that

FIG. 2. THE MEASUREMENT OF THE INSENSIBLE PERSPIRATION OF HUMANS.

with man the heat output, the carbon-dioxide elimination and the oxygen absorption are so closely related that by measuring these along with certain other factors it is possible to determine the intensity of vital activity. The experiments may be called "balance experiments." The object of such experiments is best illustrated by considering man as a bank. His food and drink and the oxygen which he absorbs from the air represent his income or his deposits. The urine and feces which are excreted, the water vapor lost from the skin and lungs and the carbon-dioxide exhaled represent the outgo or the withdrawals from the bank. The balance between these deposits and withdrawals or between the income and outgo can be measured in terms of energy by means of calorimeters. If there is no draft upon body material, obviously the energy of income and outgo should balance. If they do not balance, the difference in energy is a measure of the drafts upon or additions to the body stores. Atwater's findings along this line show that the law of the conservation of energy obtains even in as complex a system as the human body. Vitalism as such played no rôle in these experiments, for Atwater was considering *matter* and energy. But the most important outcome of these complete balance experiments was the finding that the carbon-dioxide production, the oxygen consumption and the heat output (which Lavoisier had shown to be the result of life processes) are so closely correlated with each other that in order to determine the level of vital activity one need no longer use the complicated, expensive, time-consuming calorimeter for measuring the heat elimination, but can measure the oxygen consumption alone (a measurement calling for a far simpler technique) and therefrom calculate the heat production.

It was natural that the heat output rather than the oxygen consumption should have been the first factor to be measured, since it is evident that all warm-blooded animals are constantly giving off heat. Each adult is giving off about as much heat as a 100-watt electric lamp. If such a lamp were placed in each chair in a lecture hall, for example, the lecturer and the audience would soon be aware of a feeling of heat from each of these sources. The fact that the heat in the lamp is concentrated, however, makes it difficult to compare it with the heat given off by an individual. We have all had the experience of trying to unscrew an electric light bulb from a

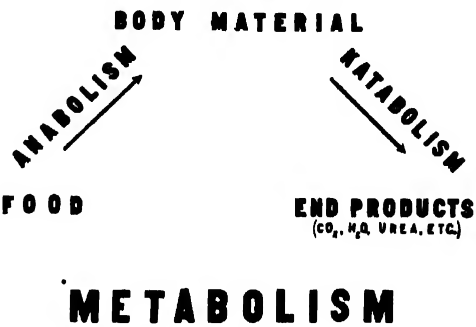


FIG. 3.

fixture immediately after turning off the current, and we know that the bulb can be extremely hot. If one had a large lens or burning glass and could focus the heat given off by the body down to such a fine point as that represented by the lamp, then the heat output of the individual would be found to equal that given off by the 100-watt lamp. But our body temperature is essentially constant. If heat is lost from the body, heat must also be produced. What regulates the production of heat and what factors most profoundly affect it? Under ordinary conditions there are two distinct phases in the processes of life, (1) the building up of body material from food material (anabolism) and (2) the

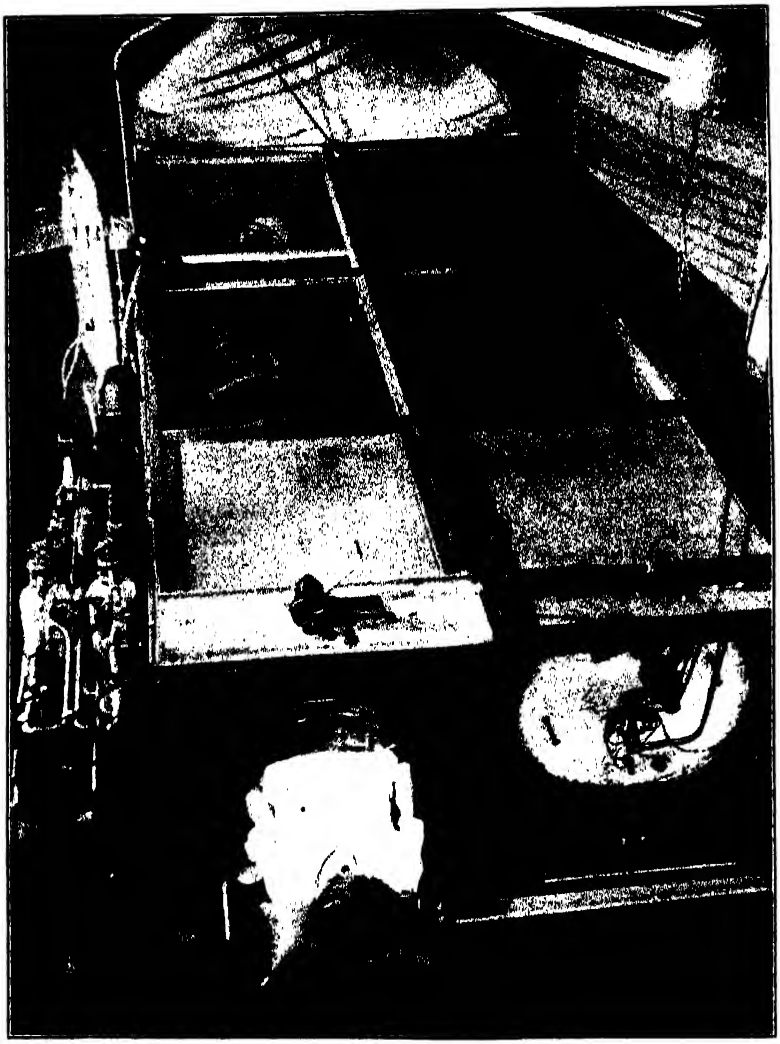


FIG. 4. A SO-CALLED "EMISSION CALORIMETER" FOR MEASURING THE HEAT PRODUCTION OF HUMANS.

breaking down and oxidation of this body material into its end products, chiefly carbon-dioxide, urea and allied compounds (katabolism).

In common parlance no distinction is made between the words "anabolism" and "katabolism," because almost invariably we are considering katabolism. When we speak of a study in metabolism, therefore, we mean usually a study of katabolism, that is, the breaking down of body material, and it is in this phase that heat is developed.

One of the earliest conceptions of the reason for heat production was that the body must be warm in order to function properly and that heat is produced *to keep the body warm.* The body is ordinarily in an environment much cooler than the body temperature. It is thus constantly losing heat to the environment, and in order to keep the body

cells at the proper temperature heat must be produced. This view considers heat production as the *main object* of the chemical processes in the body. Another conception is that heat is a *waste* product, given off *as the result* of muscular motions or chemical transformations arising for an entirely different purpose. We need not go into an extensive analysis of the various lines of reasoning leading to these conceptions, except to point out the two main facts that we are producing and giving off heat all the time and that we all have a body temperature which is essentially uniform. But the fact that the normal body temperature is in general constant does not signify by any means that all individuals have the same heat production. Because all houses are heated to 70° F. does not mean that the same amount of coal is burned in each cellar, for houses differ in size and construction. Similarly with man, the differences in vital activities mean differences in heat production.

One of the first things learned in the study of vital activity was that heat is not produced solely to keep the body warm. It is the result of life processes, an end product or, we might say, a waste product. As the boiler, in order to produce power, must give off a large amount of heat, so is human heat production likewise necessary in order to furnish motive power for human activities. The relations between the power plant and the production of work interest the engineer extremely, but the heat production of man and its relation to vital activity, indeed physical activity, interest us all because we are producing heat all the time. The economist is soon to be as much interested in the heat production and productive labor of man as he is in the efficiency of the newer types of power plants.

It was found with the calorimeter experiments twenty-five years ago that large individuals have a greater heat production than small individuals, although all have essentially the same body temperature. It was also found that the eating of food increases the heat production and that muscular activity, particularly, increases it enormously. Accurate metabolism studies to determine the effect of any special factor can not be made, therefore, unless the conditions of study are the same in all cases. Each animal, even in repose and without food, is continually producing heat—at a low rate, to be sure, but at a rate commensurate with the low vital activity under such conditions. This low heat production, measured under certain reproducible conditions, has been called the "basal metabolism." The conditions considered prerequisite for the measurement of this basal metabolism are that one should be in complete mental and muscular repose, usually after lying thirty minutes on a couch, neither too cold nor too warm, but comfortably relaxed, at least twelve hours after the last meal (which should not have been too rich in protein), with a normal body temperature, and awake. The metabolism would be even lower during sleep and still lower during prolonged fasting, but it is impossible to insure that all individuals will sleep during the period of measurement and fasting is undesirable.

In the early days of metabolism measurements the necessity for ruling out all controllable factors affecting metabolism was not recognized. A certain degree of movement was allowed. The periods of measurement were several hours long and not sharply defined, and the measurement often included both the metabolism during repose and that during moderate activity. The gross factors can be studied fairly well with the calorimeter, but the calorimeter is sluggish in action, designed for long periods of measurement, and transitory

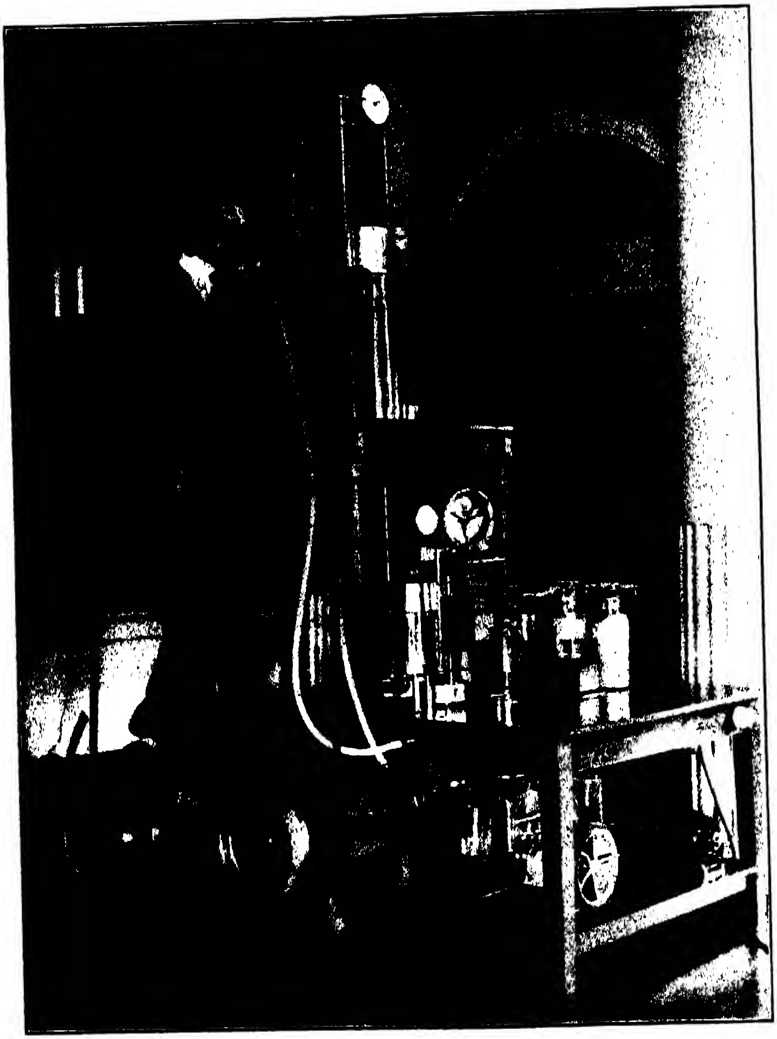


FIG. 5. MEASURING THE HEAT PRODUCTION DURING WALKING.

effects can not easily be recorded. Furthermore, the calorimeter is costly and difficult to operate, requiring a staff of highly trained operators. Fortunately, however, since calorimeter experiments have demonstrated the close relationship between the heat production and the respiratory exchange, it is now possible to obtain a good index of vital activity by measuring either the carbon-dioxide production or the oxygen consumption alone. Respiration apparatus for such measurements can be secured at an inconsiderable expense and require the service of but one technician. Short periods are possible with the respiration apparatus, and hence any transitory changes in metabolism can be measured. The determination of the carbon-dioxide production is not difficult, for the carbon-dioxide in the expired air can be collected and weighed, or the air expired can be analyzed for its carbon-dioxide content. Indeed the carbon-

dioxide output of man or animals is as easily measured as the engineer measures the gases in the chimney flue of the power plant. For years this measurement of the carbon-dioxide production was that most commonly used as an index of vital activity. Later on it became just as easy, in fact, easier, to measure the oxygen consumed by a man, and the newer forms of respiration apparatus are for the most part constructed for the measurement of the oxygen consumption alone.

In these forms of apparatus the carbon dioxide produced is absorbed by soda-lime and the reduction in the volume of air in the closed circuit is measured either by the fall in height of a spirometer bell or by the amount of oxygen to be introduced into the closed circuit to bring the volume of the system back to its original point. The spirometer bell is the dominant feature in the laboratory apparatus in most general use.

The oxygen consumption is a somewhat more accurate measure of the heat production than is the carbon dioxide exhaled. Since each liter of oxygen used in metabolism is accompanied by a heat liberation of about five calories, the heat production can be easily computed from the measured volume of oxygen consumed. The measurement of the heat production has thus become a simple process, now available to every student in the physiological laboratory.

The establishment of simple methods of measurement and the recognition of the necessity for reproducible basal conditions made possible studies on the influence of many different factors upon vital activity. Is the basal metabolism constant from hour to hour? From day to day? How is it affected by sleep, by ingestion of food and by muscular work, all factors entering into every one's daily life? These problems

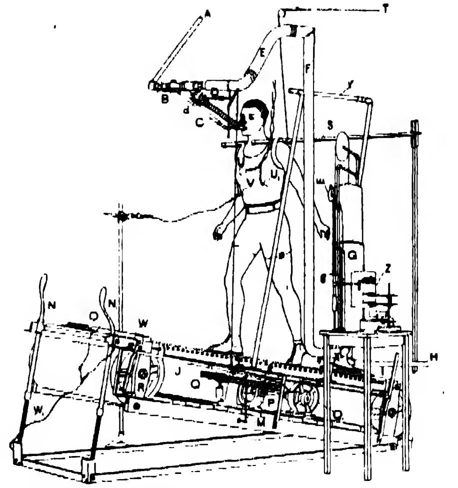


FIG. 6. SCHEMATIC OUTLINE OF APPARATUS FOR DETERMINING THE HEAT PRODUCTION DURING WALKING.

can all obviously be studied with one person. But in the broader field of comparative physiology it becomes necessary to study different individuals, and then the effects of body size, weight and height, age and sex must be determined.

TABLE 1

CONSTANCY IN BASAL METABOLISM IN CONSECUTIVE 10-MINUTE PERIODS

(Mr. C., January 26, 1925)

Period	Oxygen consumed per minute cc.
I	219
II	220
III	219
IV	230
V	223
VI	225
VII	225
VIII	229
IX	223
X	223
XI	222

More recently race has also been suggested as a potential factor affecting metabolism, and here again the study must be made with numbers and not with a single individual.

Countless respiration experiments dealing with these and other problems

FIG. 7. RECENT MODEL OF APPARATUS FOR DETERMINING THE OXYGEN CONSUMPTION OF A HUMAN.

have now made certain facts in the field of metabolism sufficiently clear to permit of discussion. Thus, it has been found that the basal metabolism of the same individual remains reasonably uniform on any one day and likewise from day to day, when the conditions of measurement are the same.

It will be of interest to note what is the effect, for example, of the ingestion of food upon this fairly constant basal metabolism. In a typical series of measurements made before and after

TABLE 2

CONSTANCY IN BASAL METABOLISM ON CONSECUTIVE DAYS.—MR. C.

Date	Oxygen consumed per minute cc.
April 21	217
" 22	215
" 23	214
" 24	218
" 25	229
" 28	222
May 5	216
" 10	225
" 19	221
June 24	226
" 25	219

the ingestion of one hundred grams of cane sugar the oxygen consumption prior to the eating of the sugar was two hundred cc per minute, and twenty-five minutes after the sugar was eaten it had increased to 244 cc. This finding is of special importance, since it indicates the necessity for avoiding any stimulus to digestion during the period of basal metabolism measurement.

Muscular work has a still more pronounced effect than the ingestion of food. Even small muscular movements affect the basal metabolism, and by severe muscular work the metabolism may be increased tenfold. The accompanying photographs show the method of studying the metabolism of a man during the severe muscular work of walking on a treadmill at a rapid rate or working at a drill press. In our consideration of basal metabolism such studies are of the greatest significance in showing the necessity for avoiding any muscular activity. Complete muscular repose is imperative.

Having seen that the eating of food is accompanied by an almost immediate

FIG. 8. A HEAD CHAMBER OR HELMET FOR MEASURING THE OXYGEN CONSUMPTION OF A HUMAN.

FIG. 9. MEASURING THE OXYGEN CONSUMPTION OF A MAN WHILE WORKING AT A DRILL PRESS.

increase in metabolism, we naturally ask, "How does the complete withdrawal of food, or fasting, affect the metabolism?" Studies on this point have shown that during fasting the basal metabolism becomes lower and lower each day. One of our subjects (shown in the accompanying photograph) fasted for thirty-one days, and as can be seen from the chart, his heat production throughout this period decreased continuously. It is obvious, therefore, that for the comparison of different individuals the basal metabolism can not be measured after prolonged fasting.

Rarely does the body weight of the individual change to such an extent as the result of fasting to have fasting *per se* enter into any such comparisons. Undernutrition may, however, frequently appear, not only with the same individual, if studied over a long period of time, but with two individuals otherwise comparable, except that one is poorly nourished. Undernutrition results in a marked lowering of metabolism. A group of twelve men, who were subjected for four months to reduced rations amounting to about one half the normal intake, lost twelve per cent. of their body weight and their metabolism fell off 25 per cent. or more. This finding is sufficiently striking to emphasize that the state of nutrition of the body is an important factor in assessing the value of basal metabolism measurements.

Is the decrease in metabolism noted with fasting due specifically to the fasting or, since the individual is smaller at the end of the fast, is it due to the pronounced change in body size? A great many measurements have been made upon people of widely different weights,

TABLE 3

BASAL TWENTY-FOUR-HOUR HEAT PRODUCTION

New-born infant (3.5 kg.)	143 calories
Adult man (70 kg.)	1,700 calories

and values are now available which show that the average new-born baby, weighing 3.5 kg., has a twenty-four-hour basal heat production of 143 calories, the average thirteen-year old girl,

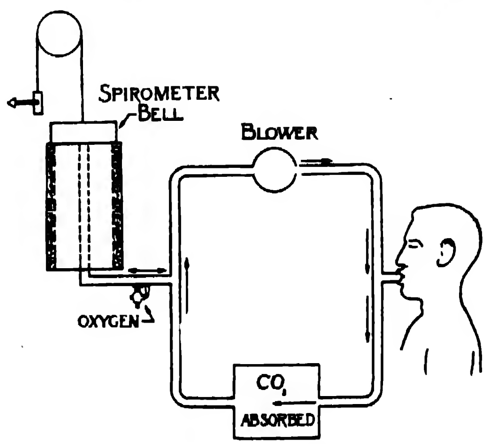


FIG. 10. SCHEMATIC OUTLINE OF APPARATUS FOR MEASURING THE RESPIRATORY EXCHANGE OF MAN.

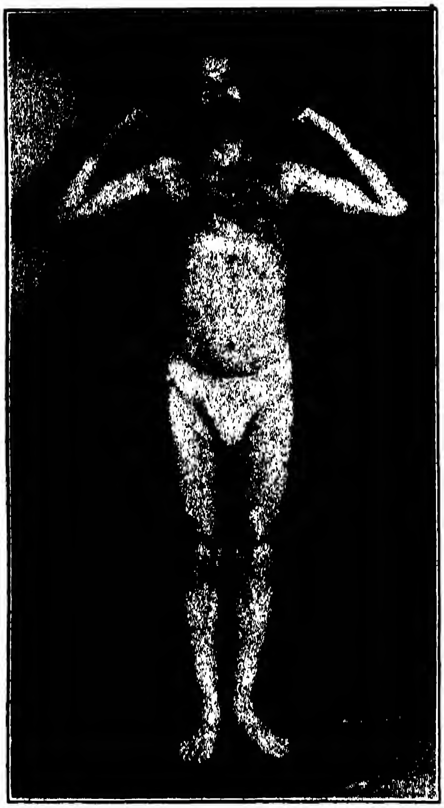


FIG. 11a. BEFORE THIRTY-ONE-DAY FAST.

weighing 42 kg., has a heat production of 1,200 calories, and the average man, weighing 70 kg., has a heat production of 1,700 calories. Thus, the heat production of the small baby, with less than one tenth the weight of the thirteen-year old girl, is considerably more than one tenth of her heat production and one twelfth of the heat production of an adult man weighing twenty times as much. The baby, therefore, has a high heat production per unit of weight. Some attempt to allow for size, however, is logical, and the heat per unit of mass, usually per kilogram of body weight, was computed to be used for the basis of comparison. From such data we have plotted a curve comparing the heat production per kilogram of body weight with the body weight, for new-born infants, boys and men up to 94 kg. in weight. This curve shows that the heat production on this basis increases rapidly up to about 8 kg. and then falls off again, reaching a fairly constant level at 74 kg.

At first it was supposed that two individuals could be compared with each other if they were of the same weight, but it was soon discovered that the tall, thin man has a metabolism different from that of the short, fat man, even if they are both of the same weight. Height is, therefore, another factor which affects metabolism. With weight and height, age is also more or less closely correlated, for low weight and low stature are coincident with youth

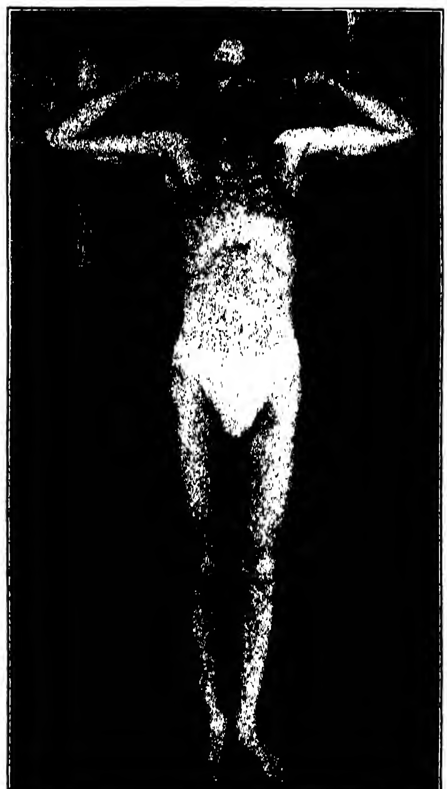


FIG. 11b. AT END OF THIRTY-ONE-DAY FAST.

and greater weight and greater stature with adult life. As the number of basal metabolism measurements gradually increased, it became possible to study the effect of age. Ideally it would be desirable to measure the same individual from birth to old age. That was impracticable. At first most of the measurements were made on people of college age, as it was easiest to obtain volunteer subjects among college students. Later we were able, through the splendid cooperation of Dr. Fritz B. Talbot, of Boston, to study normal children from birth (the babies were often inside of a respiration chamber forty minutes after birth) up to about twelve years of age. There was then a fairly wide gap in the data from the age of twelve to the college age, but the services of the Girl Scouts were enlisted and this gap has now been filled in for girls. Beyond the college age measurements have gradually been accumulated and now, after some twenty years of work, we have a fairly complete series of measurements from birth to old age, the ninety-year period being represented by that Nestor of American surgeons, Dr. W. W. Keen, of Philadelphia, who kindly volunteered to be measured so that the age picture might be complete.

The interpretation of these results then became a problem. How is it possible to interpret the metabolism of a child of one year in such terms as to make it comparable with the metabolism of an adult? Obviously the total metabolism can not be compared directly. We have just seen that the intensity of the metabolism per unit of weight is much greater in youth than in later years. Comparison on this basis, therefore, is only a crude one. Many years ago the conception was originated that heat is lost to the environment in proportion to the surface area of the body. From this conception the belief arose that the heat production per unit of surface area is uniform with all warm-blooded animals. Various methods for estimating the body surface were then tested, the most accurate of which, for humans, is that developed by Dr. E. F.

FIG. 12. MEASURING THE BASAL METABOLISM WITH A FIELD RESPIRATION APPARATUS.

Du Bois, of New York City. Indeed, as the result of a formula, developed by Du Bois, it is now possible, from the measurements of the height and weight, to compute the body surface with considerable exactness. With more careful measurements, both of the basal metabolism and more particularly of the sur-

face area, it transpired that the heat production per unit of area shows less variation for different individuals than it does per unit of body weight. But even on this supposedly uniform basis, as will be seen from the accompanying chart, the heat production varies considerably, especially prior to the age of fifteen or sixteen years. Thus, with newborn infants it is very low, 600 calories for each square meter of skin area. But at the age of one year or a weight of ten kilograms it is at the highest point during life. After fifteen years it is nearly uniform. The heat production of different individuals, therefore, whether compared per unit of body weight or per unit of body surface, is seen to vary with age, and the youth has a more intense metabolism than the adult.

These same curves enable us to compare boys with girls and men with women. Up to about one year of age it is seen that there is no difference in metabolism between the sexes. But thereafter the influence of sex becomes pronounced, and the metabolism of men and boys is on the average about 12 per cent. higher than that of women and girls.

When the number of metabolism measurements made by the Nutrition Laboratory on different individuals had increased into the hundreds with both sexes, a biometric analysis of the data was made with the cooperation of Professor J. Arthur Harris, now at the University of Minnesota, but at that time connected with the Department of Experimental Evolution of the Carnegie Institution of Washington. This biometric analysis showed clearly that there are four independent factors closely correlated with metabolism, namely, age, height, weight and sex. From this analysis formulas have been derived, by means of which it is now possible to predict with reasonable accuracy the probable basal metabolism of adults, knowing the age, weight, height and sex. These prediction formulas are used by many clinicians in comparing the metabolism of pathological individuals with the probable basal metabolism of normal individuals of the same physical characteristics. Du Bois, analyzing much the same data, has also suggested another method of predicting the probable metabolism, from age and body surface. The surface area prediction method is simpler, and if one does not

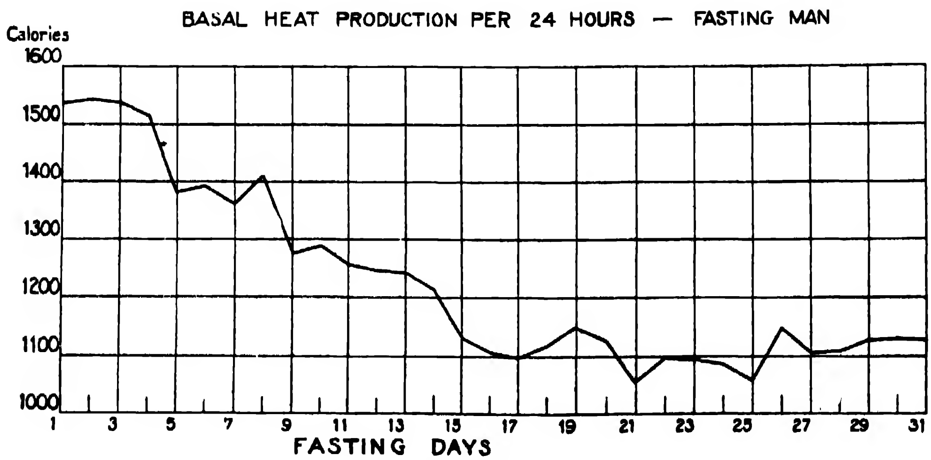


FIG. 13

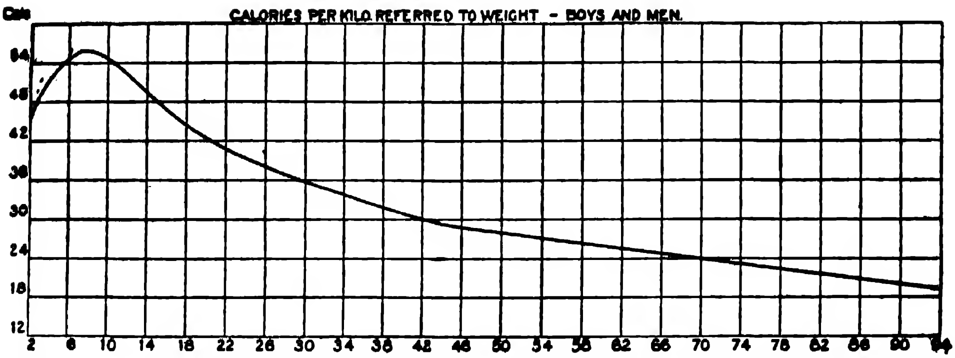


FIG. 14. THE RELATON BETWEEN HEAT PRODUCTION AND BODY WEIGHT.

ascribe too great significance to the relation between the surface area and the loss of heat from the body, the surface area is a practical basis for prediction. These prediction standards serve the purpose fairly well for the majority of the situations confronting the physician, although they are woefully deficient in old age and in early youth. Both of these methods of prediction have been used extensively by clinicians and have been a real help in many instances, but, I am sorry to say, in other instances a false guide, for exactly as the little mark of 98.6° F. on the fever thermometer has been a fetish for decades, so these so-called "prediction standards" of metabolism are becoming fetishes of the experts in metabolism, and too rigid adherence to these standards has not infrequently caused rather serious blunders. It should be recalled that the prediction method is simply an effort to aid the clinician in interpreting the measured metabolism of a patient upon whom no measurements have ever been made when he was not ill. In lieu of such measurements comparison with the predicted normal basal metabolism is the only procedure possible.

Our main theme, however, deals not so much with the prediction of basal metabolism as with the factors affecting it. How resistant is the basal metabolism to superimposed factors? One of the commonest experiences of every one is sleep. Under conditions of sleep one would expect to have the greatest degree of muscular and psychic repose. Hence the influence of sleep on metabolism possesses unusual interest for us. With the type of respiration apparatus ordinarily employed for basal metabolism measurements (see figures 7, 8 and 10),

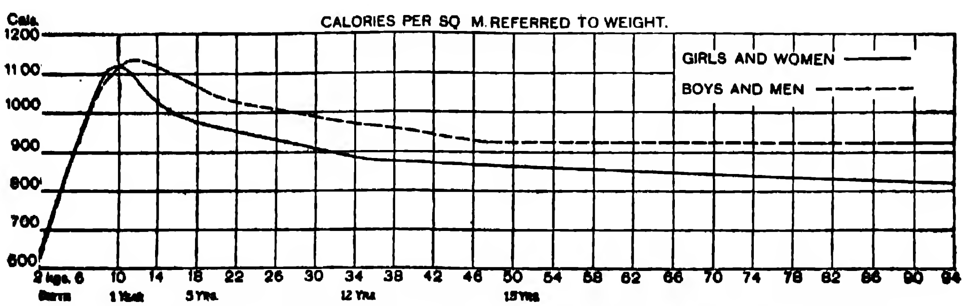


FIG. 15. RELATION BETWEEN HEAT PRODUCTION AND BODY WEIGHT.

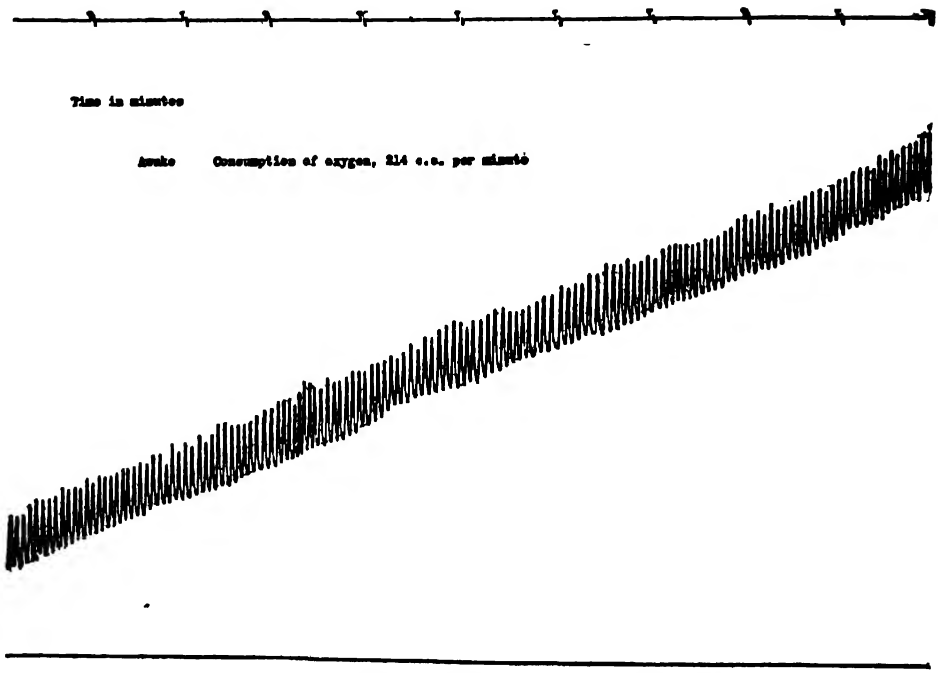


FIG. 16. CURVE OF OXYGEN CONSUMPTION—SUBJECT AWAKE.

the respiratory movements as well as the oxygen consumption of the subject are recorded graphically on paper. When the man is awake, the tracing of the respiration is remarkably uniform, as will be seen from the accompanying chart. When he is asleep, however, the tracings are by no means so regular. The measurements obtained in these two instances are typical of the differences in respiratory mechanics commonly found as a result of sleep. Furthermore, the oxygen consumption per minute, while the subject was awake, was 214 cc and while asleep, 189 cc, a drop of about 10 per cent. Hence, in view of the extremely irregular respiration and the lower metabolic level during sleep, it is clear that for practical purposes and for the reproducible conditions stipulated for basal metabolism measurements values found only when the individual is awake can be used for comparison.

Usually basal metabolism measurements are made while the subject is lying on the back. Is the metabolism any lower when the ordinary position of sleep customary with the individual is assumed? Most people sleep on the right side. It has been argued that the

TABLE 4

INFLUENCE OF BODY POSITION ON BASAL METABOLISM

Subject	Lying on	Oxygen (cc.) Consumed per minute	
Mr. A	Back	223, 226, 226	= 225
	Side	223, 226	= 225
Mr. B.	Back	227, 232	= 230
	Side	235, 238	= 237
Miss W.	Back	167, 165, 173	= 168
	Side	173, 178, 174, 173	= 175

metabolism is actually lower in this position. Recently, however, a series of experiments made with several trained subjects have shown not only that it is *impossible to obtain a lower metabolism* when the subject is lying on the side than when lying on the back, but that

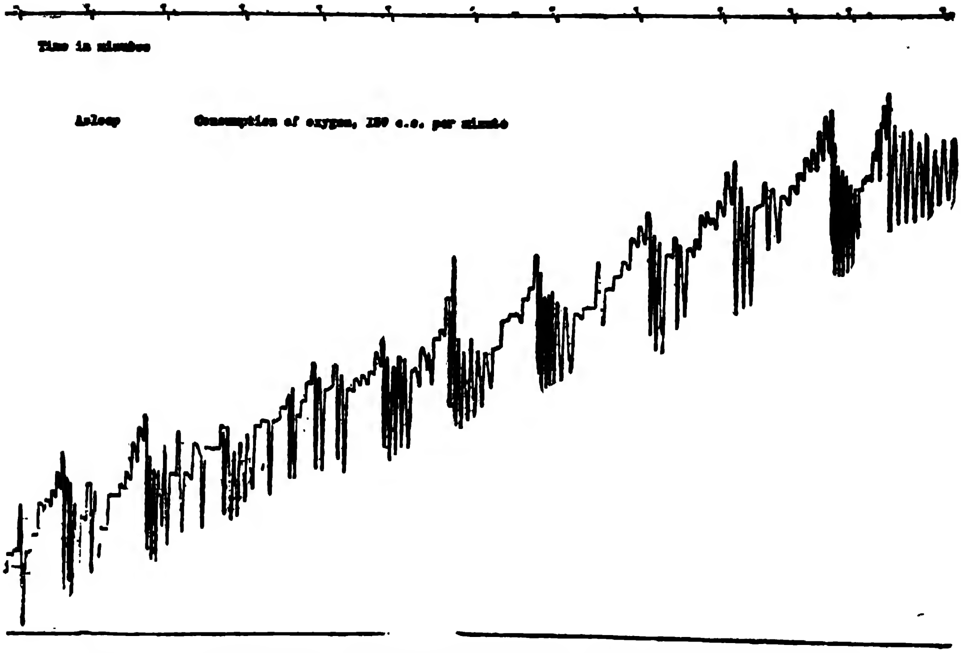


FIG. 17. CURVE OF OXYGEN CONSUMPTION—SUBJECT ASLEEP.

the metabolism is really the lowest when one is lying on the back.

It is a common experience that severe mental work is fatiguing. Most people, when lying on the back, are inclined to mental repose, but the influence of mental activity must be considered in basal metabolism measurements, for we can not stipulate that our subjects should be in complete mental repose, with the mind a perfect blank, for example. The influence of mental effort upon heat production has interested physiologists for many years. In connection with basal metabolism we are concerned more particularly with the effect of moderate mental activity rather than the intense mental effort of a mathematician, for example. But in order to study the effect of mental effort and to secure, theoretically, the greatest effect, the mental work must be sustained and severe. The problem is certainly alluring. But what is mental effort? It is necessary, first, to be sure that we can measure our people without mental effort and then with mental effort. But how can we be sure of sustained mental effort with any given individual? Will the reading of a book of poems insure it? Certainly not. Memorizing a passage? For some persons, yes, for others, no. But we agree that with the average college student there is one time (perhaps the only time in the whole year) when he experiences sustained mental effort and that is during the hours of his mid-year or final examinations. We therefore arranged with the college authorities to have twenty-two students take their examinations, one at a time, inside

TABLE 5

METABOLISM DURING MENTAL WORK

QUANTITIES PER HOUR

	Examination period	Control period
Carbon dioxide	33.42 grams	32.76 grams
Oxygen	27.30 "	25.86 "
Water vapor	39.23 "	37.80 "
Heat	98.80 calories	98.43 calories

Averages of forty-four experiments

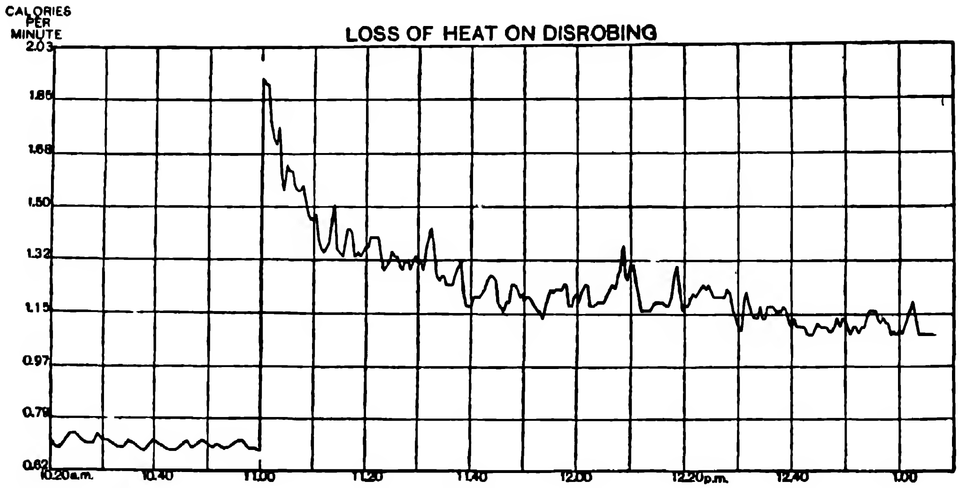


FIG. 18

of a respiration chamber, which was likewise a calorimeter. Subsequently, as a control, each was studied in the calorimeter at a period some time after the examination. To include the mechanical work of writing, the students were told to copy some simple prose which was extremely uninteresting to them. The measurements were not made under basal conditions, but the *only* factor which differed in the two series of experiments was the mental effort. Under such conditions the specific effect of mental effort, if any, should be noted. The measured metabolism, when the men were under severe mental strain, compared with the measured metabolism during the control period showed no significant effect of mental effort. This is very disillusioning to many of us.

What is the effect of psychic unrest, as expressed by mental agitation, distress, anger or unhappiness? To plan experiments definitely along this line is obviously difficult. Incidentally, at the Nutrition Laboratory a few years ago my associate, Dr. T. M. Carpenter, was studying the metabolism of an assistant nearly every consecutive morning, and this assistant had ordinarily shown an unusually uniform heat production. He was well trained, remained very quiet during the measurements, and there was nothing novel in the situation for him. One morning, when Dr. Carpenter thought he was particularly quiet and relaxed, the metabolism was greatly increased. Instead of being satisfied with two or three test periods, as usual, Dr. Carpenter made still more, and the metabolism still remained high. There was no fever, and no other cause for the increase was apparent. Questioning, however, brought out the fact that the evening before the young man had attempted to elope with one of the young ladies of the laboratory and her father had kicked him down three flights of stairs into the street, which resulted in a great deal of physical as well as mental unrest. The next morning he was experiencing the after-effects in the shape of a considerably increased metabolism, which showed even above the seeming muscular exhaustion and somnolence.

These studies on the factors affecting basal metabolism covered a number of years, and during this time the Nutrition Laboratory obtained repeated measurements on four different staff members at

fairly frequent intervals. Hence we now have available evidence regarding the effect of age with one and the same person, unfortunately not during the rapid period of growth from birth to puberty, but at least for the period between twenty-five and sixty years of life, including the more critical period at about forty to forty-five years. From this evidence it is apparent that from about forty years on there is a distinct tendency for a decreased metabolism, both in the measured heat production and in the pulse rate.

With one of the subjects, a woman, the age range studied happened to be between twenty-five and thirty-five years, and during this particular age range it was found that the metabolism in general remained essentially unaltered. Rather frequently, however, when the metabolism was the lowest, it was coincidental with menstrual days, and although this subject, an artist's model, is unusually normal and but little inconvenienced by the menstrual period, it was thought that a slight feeling of malaise might have caused this lower metabolism.

We all have days when we feel below par and days when we feel better than on other days. Is this reflected in the basal metabolism? The periodic experience of normal women with menstruation is usually accompanied by a feeling of malaise, and measurement of the metabolism during the period of this normal, regular function is perhaps one of the simplest methods of studying the effect of feeling below par. We have just completed a series of daily measurements of the metabolism with this same woman over a period of two months, in which it is seen that although this normal function causes her practically no inconvenience, there is a distinct tendency for the metabolism to be slightly lower during the menstrual period.

A common remedy for "that tired feeling" or the sense of being below par is rest and relaxation. It is for this reason that high-school and college students have the Christmas and Easter recesses, and it is for this same reason that practically every one, both the student and the working person, enjoys a vacation during the summer. The habits of life during the summer vacation are decidedly altered. From a sedentary life indoors we change to a life out-of-doors in the sunlight. We indulge in more muscular activity, such as long hikes, swimming and boating, and we eat more fresh vegetables, berries and fruits. How is the metabolism affected by such a change in the living conditions? This effect again has been studied by the Nutrition Laboratory on twenty-two different individuals, both men and women. These subjects were members of the laboratory staff, accustomed to indoor desk and laboratory work, and the occupation prior to the vacation was typically sedentary. The vacation period extended

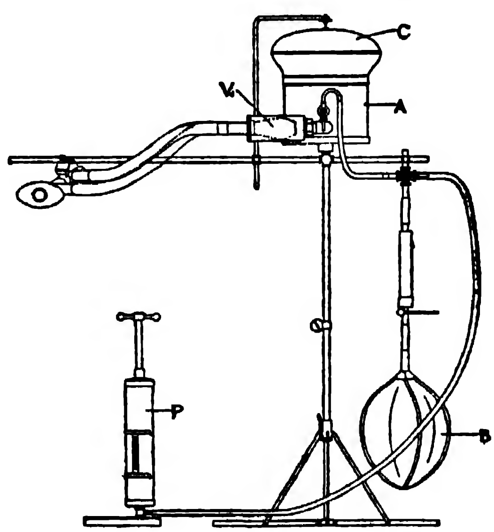


FIG. 19. DIAGRAM OF A FIELD RESPIRATION APPARATUS FOR USE ON EXPEDITIONS IN MEASURING THE OXYGEN CONSUMPTION OF HUMANS.

through the entire month of August, and the metabolism was measured with each subject on at least two different days in July and again on two days in September. The subjects were questioned as to the nature of their vacations and in every instance indicated that the vacation was characterized by greater activity, more outdoor life and change in diet and in environment. Greatly to our surprise, however, it was found that in practically all cases the metabolism of these individuals was exactly the same after the vacation as before. It is astonishing that a procedure which results in such a profound alteration in the subjective feelings, that is, a summer vacation, should not have altered in the slightest the basal metabolism. This is again a strong indication of the fixity of basal metabolism.

In studying the influence of vacation, the effect of a change in season from spring to summer or summer to fall is usually involved. This naturally raises the question as to what is the effect of season. Is the basal metabolism constant throughout the entire year, provided of course there are no marked changes in body weight, or does it alter with the change in seasons? Miss Florence Gustafson, a teacher in the department of physiology at Wellesley College, cooperated with the Nutrition Laboratory in a study of this factor, and measurements were secured on twenty young women students over a period of fifteen consecutive months. The results of the experiments have been assessed only within the last two weeks, and we find that there is a tendency for the metabolism to be lowest in winter, increasing in spring, and remaining unaltered till late fall.

The debt owed to college students by physiologists is further accentuated by the outcome of a series of observations made at Mount Holyoke College, in cooperation with Professor Elizabeth Crofts. A study was being made to determine whether a night's rest in bed should precede basal metabolism measurements, that is, whether the amount of activity involved in arising in the morning, dressing and walking or taking a street car to the hospital or other place where the observations were to be made, affected the basal metabolism appreciably. It was found that the effect of such activity had entirely disappeared after half an hour of complete repose, and it was concluded that it is unnecessary to demand that the subject should be measured in bed, before arising in the morning, thus avoiding the use of a much needed hospital bed. The basal metabolism is therefore but little affected by the extraneous factors which we have thus far considered, such as body position in bed, severe mental work, or the morning activities of arising.

But in spite of the seeming constancy or fixity in basal metabolism, occasionally influencing factors arise that are most surprising. While making this series of observations at Mount Holyoke College, we noted that certain volunteer subjects, Chinese and Japanese, showed a pronouncedly low metabolism. This finding was immediately controlled by measuring a number of other Orientals, both at Mount Holyoke College and, through the cooperation of Professor Grace MacLeod, at Teachers College, New York. It was clearly established that these Oriental college women had a metabolism on the average 10 per cent. lower than the standards for American women. This difference in metabolism is all the more striking, since it can not be explained by differences in climate and diet. These young women had all been for at least one year in America, were living in the same college dormitory and eating the same food as their American college mates, and engaged in the same activities, and seemingly the only foreign factor was that of race. Certain observations in China and

earlier observations in Japan apparently point likewise to a lower metabolism with the Oriental. As a result of this finding at Mount Holyoke College, therefore, the Carnegie Institution has planned to make a fairly extensive study of the metabolism of different races, and considerable progress has already been made along this line.

The attention of anthropologists was immediately challenged by this finding with Oriental women, and the cooperation of a number of collaborators has already been enlisted. For these racial studies a special apparatus has been developed at the Nutrition Laboratory, which is light enough in weight to be readily transportable on expeditions and which permits the measurement of the oxygen consumption with great accuracy. The subject breathes through a mouthpiece connecting with a small can. This can, two thirds filled with soda-lime to remove the carbon dioxide exhaled, is covered with a light-weight rubber bathing cap, which serves as an expansion chamber. As oxygen is removed from the closed system during the respiration of the subject, the bathing cap, which was at first well distended, gradually collapses. Oxygen is introduced by a hand pump of known volume to take the place of the oxygen absorbed. The record of the number of pumpfuls of oxygen introduced and the length of time involved gives a measure of the volume of oxygen absorbed by the subject. Already eight of these appliances have been distributed to members of various expeditions. The following diagram illustrates an experiment made with the apparatus on a subject at the Nutrition Laboratory.

Thus far actual returns have been received from measurements made by Mr. Morris Steggerda, of the Department of Genetics of the Carnegie Institution, on a group of browns and blacks in Jamaica, B. W. I., and measurements made by Dr. G. D. Williams on Maya Indians at Chichen Itzá, Yucatan. The results of these measurements have been computed and the manuscripts are now ready for the printer. With a group of thirty-seven male browns in Jamaica the heat production on the average was, to be sure, 5 per cent. below the predicted heat production for white men in the north. But since a group of thirteen female browns and male blacks had a heat production perfectly comparable to that of white men and women, the evidence of a definite racial factor is obscured. The fact that the hitherto suspected depressing influence of a tropical environment did not appear in general with these browns and blacks argues again against the idea that the body produces heat to keep itself warm.

In the Yucatan series, measurements were made upon certain white members of the expedition, both before they left Boston, while they were in Yucatan and after their return to Boston. Other measurements were likewise obtained on whites who had only recently arrived in Yucatan. These measurements, so far as they go, indicate that the sojourn in Yucatan was without effect upon the metabolism of the whites, thus again emphasizing the absence of effect of a sub-tropical climate. Singularly enough, with the Mayas, all of whom were men, the metabolism on the average was over 5 per cent. *above* the northern standards for white men. Thus not only has the sub-tropical environment *not lowered* the metabolism of these individuals, but some factor, presumably racial, has asserted itself, and we have here a higher metabolism than that of the northern whites. The fact that these men were engaged in archeological excavations may possibly account for part of their increased metabolism, for an athletic person does have a somewhat higher metabolism than a non-athletic person. However, it seems clear that the degree

of muscular exertion involved in their daily occupation could not account altogether for the high level of metabolism. We believe, therefore, that we have with the Mayas a definite racial factor which is wholly comparable to the racial factor noted with Chinese and Japanese, whose metabolism was distinctly low. In view of the fact that the low metabolism of the Orientals has been interpreted by some investigators as indicating racial inferiority, this high metabolism of the Mayas and the contrast between the civilization of the Mayas at the present day and the high degree of civilization of the Orientals speak against interpreting a low metabolism as an index of racial inferiority or a high metabolism as an index of racial superiority.

Problems of racial metabolism are, of course, indissolubly connected with climate, and our recent observations in the Tropics seem to indicate that a warm environment does not lower the basal metabolism. What is the effect of cold? Man ordinarily maintains a uniform temperature for his body by adjusting his clothing to the temperature of the environment, so that changes in the weather do not have a pronounced effect. What would be the effect upon metabolism of exposure of the body to cold? Investigation of this problem gives us an opportunity to learn also what relation heat production has to heat loss. When the body is exposed to cold by removal of the clothing, there is immediately an enormous loss of heat, due to the difference in temperature potential between the skin (which is approximately 33° C.) and the air (which is ordinarily about 15° C.). As a result of this great loss of heat, the skin temperature and, indeed, the tissue temperature is lowered, thus reducing the difference in temperature potential between the skin and the environment. Finally, however, the fall in skin temperature ceases and the loss of heat is adjusted to the prevailing temperature potential.

Recently a calorimeter has been developed at the Nutrition Laboratory, which is sensitive enough to measure the heat loss in periods as short as one minute. A subject was placed inside the calorimeter, nude, but covered with several blankets. The loss of heat under these conditions was first measured for about one hour, and found uniform. By means of cords inside the chamber, the blankets were then suddenly rolled away and the nude body was exposed to the cold air. As can be seen from the curve herewith, there was immediately a pronounced loss of heat. Finally the heat loss reached an approximately constant level, but the loss was still greater than it was before the blankets were removed.

How does the heat *production* compare

TABLE 6

EFFECT OF SHIVERING UPON OXYGEN CONSUMPTION PER MINUTE (SUBJECT LYING, NUDE, AT 9:14 A. M.; ROOM TEMPERATURE, 11° C.)

Time	Oxygen consumption	Remarks
A. M.	cc	
9:30	211	
10:10	221	
10:40	275	Shivering
10:55	286	Shivering

with heat *loss*, especially when the loss of heat is very great? The heat production, as we now know, is best measured by the oxygen consumption. It has been found that the oxygen consumption or the heat production increases with exposure to cold, as does the heat loss, but not to the degree that one would expect. Thus, experiments were made with the same subject studied in the calorimeter, an artist's model who was well trained to posing without clothing. After lying for fifteen minutes, nude, in a cold room at 11° C. (52° F.), the subject's oxygen consumption was 211 cc. per minute, as seen from this table. During the next forty minutes of continued exposure there was but a small increase (5 per cent.) in the oxygen consumption, al-

though the room temperature was very cold for a nude person. Indeed, only when the point of shivering, which is in reality a form of muscular work, was reached, was there any considerable rise in metabolism. This indicates that only under extreme conditions and as a last resort is heat produced to keep the body warm, *i.e.*, when there is an unusually great loss of heat to the environment. Under ordinary circumstances, however, heat production is an end product and not the main object of life.

Another indication that heat is not produced primarily to keep the body warm was obtained in experiments which Mrs. Benedict and I have made on the effect of a neutral bath. In basal metabolism measurements it has been the custom to have the "room temperature" presumably somewhere between 15° and 20° C., and to make certain that the subject is comfortably relaxed, neither too warm nor too cold. Little, if any, attention, however, has been given to recording the kind and amount of clothing and bed covering. It has been suggested that if the body were immersed in a neutral water bath at 35° or 36° C. (*i.e.*, at essentially the same temperature as that of the body), the metabolism measured under such conditions would be the true basal, that is, it would be lower than when measured under the ordinary conditions prescribed for basal measurements. Another suggestion has been that the metabolism is at its lowest point *after* the subject has left the bath and has been lying down for some time. These suggestions were tested with several subjects, whose metabolism was measured, first, while they were lying clothed and lightly covered, in a room at 15° C., then while they were immersed in a neutral water bath at 35° C., in a very warm room (30° C.), and subsequently after the bath, when they were again lying down, well covered. The results of two of our experiments are shown in the accompanying table, from which it is seen that there is a slight *increase* in metabolism during the bath

TABLE 7

INFLUENCE OF A NEUTRAL WATER BATH (36° C.) UPON THE OXYGEN CONSUMPTION (CC.) PER MINUTE

Condition	May 13	May 14
Before bath (lying, clothed)	177	168
In the bath (96.8° F.)	188	185
After the bath (lying, well covered)	176	167

and that afterwards the metabolism returns to its initial level. It is, therefore, clear that the neutral water bath does not lower the basal metabolism and that the ordinary room temperature is a satisfactory thermal condition for making basal measurements on the clothed and suitably covered subject.

These neutral bath experiments indicate that heat is not produced to keep the body warm, for the conditions during the bath were such that but little heat could be lost from the body and yet the level of the oxygen consumption or the heat production was not lowered. The problems of heat production are, however, subtle. The muscles, without doubt, produce the most heat when we are up and actively about, but the cells produce a great amount of heat by themselves, and when the body is overheated the chemical action becomes tremendously accelerated, as in fever.

We know that in disease there are great changes in metabolism, even when the individual is lying quietly. In toxic goiter, for example, the basal metabolism is increased 60, 80, or even 100 per cent. and in another thyroid disease, myxedema, it is greatly decreased, 40 or 50 per cent. These changes are now explained by the fact that there is normally discharged from the thyroid gland a substance (thyroxin), a so-called "hormone," which stimulates metabolism. When it is discharged in excess, as in

toxic goiter, the metabolism is increased, and when its discharge is deficient, as in myxedema, the metabolism is decreased. In this latter case, fortunately, it is now known that administration of the pure product will increase the metabolism greatly. The intelligent use of basal metabolism measurements has been of considerable aid to clinicians in handling these two diseases. In fact, basal metabolism measurements are practically a prerequisite to establish the clinical picture for all patients with either toxic goiter or myxedema. Hundreds of basal metabolism measurements are made each week in the United States alone on patients of this type.

Fortunately the majority of individuals are not afflicted with disease. A more common affliction is overweight. During youth and the period of rapid growth, indeed up to thirty years of age, statistics show clearly that overweight is a distinct asset towards longevity. Beyond thirty years it becomes a liability of no mean significance. But the keen appetite for food so fortunately provided for us by nature during the period of youth and activity has established such a firm habit upon us that the tendency is to keep up the food intake, notwithstanding the fact that with advancing age the physical activities are lessened and there is therefore an ever-decreasing heat output. The inevitable result is increase in weight, which begins with plumpness, passes through embonpoint and finally ends up in obesity, which should always be called *fatness*. The chief cause of obesity is overeating. Contributory factors may be errors of diet, errors in exercise and certain pathological conditions. But when you eat a little more than you burn up, it must be deposited in the body. The insidious way in which a small daily excess may contribute to build up fat is illustrated by the fact that if but one small pat of butter, corresponding to ten grams, is eaten *in excess* of one's needs each day for a year, it will cause an increase in weight of eight pounds. Two extra lumps of sugar eaten each day throughout a year, or the equivalent amount of candy (a nougatine, for example), would also cause the same increase in weight.

Basal metabolism measurements have been of incalculable service in studying the various types of obesity, and when dietetic restrictions are to be supplemented by medication, such as the administration of thyroid to whip up the internal metabolism, such measurements are imperative. Fortunately for most people intelligent dietetic control will permit of weight reduction. But as the increase in weight is usually not sudden, but comes on with insidious surety during two, three or more years, the removal of weight must likewise not be sudden but slow. The effect of rapid loss of weight is of course most strikingly shown with the fasting individual. The man who fasted thirty-one days at the Nutrition Laboratory lost twenty-nine pounds and he looked it. (See Fig. 11a and 11b, page 14). For the ordinary person rapid reduction is a distinctly dangerous procedure. A mild reduction in food intake, even no more than simply ruling out visible fats, will accomplish a great deal. But it must not be forgotten that obesity is a condition which really demands the fullest cooperation with a skilful physician. Frequently the physician will employ basal metabolism measurements as an index of whether the patient is tolerating the weight reduction.

Exactly as basal metabolism measurements are used by the physician as a general index of the intensity of vital processes with the overworking organism of toxic goiter and with the underworking organism of myxedema, and exactly as these measurements are used to help him in his control and treatment of obesity (along with numerous other

pathological cases), so basal metabolism measurements are becoming more and more to be looked upon as the best index of the vital activity of any individual. To a certain extent the basal metabolism may be considered as the "indicator card" of the human engine, showing its general efficiency, not, to be sure, for muscular work, as in the case of the mechanical engine, but at least for the overhead maintenance of the well-functioning body prior to putting on the superimposed tasks of daily life, whether these be mental or physical. For physical capacity further testing of course is necessary, particularly in severe muscular work. But even here metabolism measurements superimposed upon basal metabolism measurements are giving the best picture of the capacity of the body for physical exercise, the relationship between external muscular work performed and the actual energy required to perform it and the efficiency of the human body as a machine. These represent special uses of metabolism measurements and are always interpreted in terms of the basal metabolism. For every healthy individual, therefore, there is a normal, remarkably fixed basal metabolism which, as we have seen, does not undergo changes even with considerable superimposition of other factors. When the basal metabolism profoundly alters, it is usually due either to disease or to some profound change in the general makeup. This change may frequently be a betterment of the organism, or not infrequently it represents a stage of being below par. In this sense, therefore, measurement of the basal metabolism is a splendid index of the level of vital activity, and it is highly probable that in the next decade we will find that basal metabolism measurements will be included in the annual physiological and medical survey which doubtless all of us will consider essential.

THE FUN OF BEING A SCIENTIST

By Dr. J. O. PERRINE
AMERICAN TELEPHONE AND TELEGRAPH COMPANY

Levity and laughter are recognized as attributes of Will Rogersian jesters, but popular opinion gives them no place in the life of a research scientist. Fun and profundity have always been placed in the same class with oil and water. They are never mixed. Pep and personality are the *sine qua non* of wild-cat stock salesmen, but absent-mindedness, self-effacement and a fish-tail handshake are accepted by the world in general as the inevitable concomitants of brains as exemplified by professors. They and other savants have ever been pictured and portrayed as myopic and sadly in need of tonsorial attention. War heroes, motion picture stars and fleet half-backs are pointed to with pride, to borrow the politician's lingo, while a life devoted to biology or mathematics, acknowledged to be commendable and altruistic, is not accepted as a model for flaming youth. There are many who believe that Captain Kidd and Robin Hood are the only ones who really ever lived. Magic carpets and Aladdin's lamps are pure fiction pulled out of fairy tale books by Douglas Fairbanks.

It is granted that scientists and professors do not generally display their enthusiasm and abandon to joy like the Yale students playing goal posts on Soldier's Field. The former have their fun on a Saturday afternoon working in a laboratory, perhaps malodorous and dark, while the latter have their particular brand of fun standing in the rain and getting sore throats yelling, "Block that kick! Block that kick!" If the devotees of Ike Walton see no fun in looking through a microscope or scrutinizing test tubes or listening to radio signals coming from half way round the world, nothing is proved. It all depends on what kind of fun one likes best. The scientist has his kind and feels no need of pharisaic sympathy or condescending condolences.

The only justification for setting down these musings is that having seen something of fun inside and outside scientific circles, there is a possibility that the recital of a few instances inside the circle will afford a little fun and the semblance of a thrill to those outside. Not ever having made a hole in 1, a 3 on a par 4 once caused the writer to unleash a yell. He has never made a great discovery in science, but he has done some work recognized to be worthy of publication. He has made a touchdown in the last minute of play after catching a forward pass, and from a lofty tier in the La Scala at Milan, heartily enjoyed the antics of Ping, Pang, Pong, singing in Puccini's Turandot. It has been his privilege to visit practically all the great physical laboratories of America and a goodly portion in Europe, to know famous scientists at home and abroad and to see and feel some of the enthusiasm and fun which charge the atmosphere at Leiden, Cambridge, Cornell and Johns Hopkins.

Exhibit A

The antagonism to Galileo and his hated telescope became very strong in his day. The clergy began to denounce him and his methods. One ecclesiastical opponent became known as a punster by preaching a sermon from the text, "Ye men of Galilee, why stand ye gazing up into Heaven?" Galileo had turned his telescope toward Jupiter and saw its satellites. On the moon he had discov-

ered mountains and craters. In 1610, Galileo wrote to Kepler as follows:

> Oh, my dear Kepler, how I wish that we could have one hearty laugh together! Here, at Padua, is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the moon and planets through my glass, which he pertinaciously refuses to do. Why are you not here? What shouts of laughter we should have at this glorious folly! And to hear the professor of philosophy at Pisa labouring before the Grand Duke with logical arguments, as if with magical incantations to charm the new planets out of the sky.

Shades of Sir Andrew Aguecheek and Sir Tobey Belch in riotous laughter in the tavern of "Twelfth Night."

Exhibit B

Galileo was born on the day of Michel Angelo's death. One might fancy that this signified the passing of the scepter from art to science, for science was destined to receive a great impetus from this remarkable man.

The young lady strolling through the garden on a clear night and who to her escort expressed admiration of the astronomer's ability to know the names of the stars envisioned the deciphering of millions of names. As a matter of fact, a person can see with the unaided eye only about three thousand stars. All persons over the entire face of the earth can see less than ten thousand stars. Galileo made a simple telescope, pointed it toward the heavens and revolutionized human thought because he multiplied the number of visible stars one hundred times. With the aid of long, photographic exposures and modern developments of the telescope, a billion of stars have been revealed. How many stars are still behind the veil, of course, is not known, but there are many, no doubt. Have the astronomers any fun? They sit up until three o'clock in the morning to see a star in the heavens, not in a theater or cabaret. Do they have to see a Ruthian homer with the bases full to get a thrill?

Exhibit C

The aurora borealis is a most gorgeous spectacle. Streamers of light and bands of color flash across the sky and quiver in the zenith. Man has simulated the aurora borealis, sending a current of electricity through a long glass tube from which the air has been pumped out. If one tries to send a current of electricity with the tube full of air, nothing much happens, but after the vacuum pump has done its work for a little while, streaks of purplish light become visible. Then areas of rose-colored tints, then striae shift from one end of the tube to the other. With the vacuum pump still working, black areas develop, and later brilliant blues and greens delight the eye. In 1893, Sir J. J. Thomson wrote the following:

> The phenomena attending the electric discharge through gases are so beautiful and varied that they have attracted the attention of numerous observers. The attention given to these phenomena is not, however, due so much to the beauty of the experiments as to the widespread conviction that there is perhaps no other branch of physics which affords us so promising an opportunity of penetrating the secret of electricity; for while the passage of this agent through a metal or an electrolytic is invisible, that through a gas is accompanied by the most brilliantly luminous effects, which in many cases are so much influenced by changes in the conditions of the discharge as to give us many opportunities of testing any view we may take of the nature of electricity, of the electric discharge, and of the relation between electricity and matter.

One of the phenomena of discharge which was receiving much attention at the time this passage was written was that of the "cathode rays." Years before it had been found that the discharge in a very highly exhausted tube is accompanied by the appearance of these rays emanating from the negative terminal. They cause a brilliant fluorescence of the glass wall where they fall upon it.

Roentgen in 1896, while investigating this brilliant fluorescence, made a mar-

velous discovery. He noticed that photographic plates, amply protected from ordinary light, became blackened when in the vicinity of such a tube. Continuing his investigations, he found that photographic plates would be blackened even when blocks of wood and other opaque objects were between the plate and the electrical discharged tube. One day, a key was placed between the covers of a thick book and interposed between a photographic plate and his tube. Imagine his state of mind when he found on the photographic plate a picture, more accurately stated, a shadow of the key. Among the graduate students studying under this great man the report spread rapidly that the "old man" had discovered a new kind of light, light, that will pass through opaque subjects. Not much is known of this light, this new kind of rays, and so they are called X-rays.

As predicted by Sir J. J. Thomson, these X-rays have been a most valuable tool in finding out the relation between electricity and matter. Hundreds of investigators have been at the job. They have worked long hours in tiny rooms of laboratories throughout the world, in dark rooms they have developed photographic plates and anxiously watched the plate reveal its spots of black as the liquid in the developing pan played over its surface. The applications of X-rays are household information to-day. What fun and thrills the scientists had before the days when the world at large knew about them. Who scoffed at Aladdin's lamp and magic carpets?

Exhibit D

From those in whom the wells of humor have not been dried up by the dust of things, Junior's experiment in scuffing his feet on the rug, and later pulling a tiny electric spark from grandpa's ear, will usually extract a laugh. On a cold winter morning, a young lady whose golden tresses are unmanageable on account of the electrified conditions imparted to them by a rubber comb, is at once interested and may even get some fun out of her temporarily acquired bristling bob. In both of these circumstances, the boy and girl can be regarded as an electrical instrument known as the electroscope charged to 20,000 or 30,000 volts. If on them a strong spotlight is played, they lose their electrical charge. The bristling tresses now stay where they are put and grandpa enjoys his snooze unmolested. The mere fact that light, particularly the blue portion of the spotlight, falls upon these electroscopes brings about their discharge. This phenomenon is known among the scientists as the photoelectric effect. If the light is strong the discharge is rapid. If the light is weak the discharge is slow. Heinrich Hertz, of whom one hears considerable these days of radio, first discovered this phenomenon in 1878. It is quite a common phenomenon, particularly apparent in metals like zinc and sodium, one of the elements in common salt. To definitely prove for the first time that light, a mere beam of light, an intangible wand, could be as potent in discharging an electrified body as actual contact with a metal rod, must have provided genuine joy to this young scientist living in Bonn, Germany, the home of Beethoven. Hertz made an epochal discovery, that of a relation between light and electricity. To-day, this discovery is one of the fundamentals involved in the transmission of pictures over wires and also that most recent achievement, television.

Exhibit E

Consider further experiments with electroscopes, the work of man's fingers. A scientist's electroscope consists of two strips of gold leaf suspended from a metal rod and put through the sulphur

stopper of a glass bottle. When the expert maker of signs uses gold leaf to place letters on the glass windows of a candy shop, he usually gets an audience because of his dexterity and also because the thin, flimsy sheets of gold leaf are interesting in themselves. Now when this electroscope is touched by the rubber comb which created the bristling bob, the gold leaves diverge. If a tiny speck of radium, that most interesting element discovered by the Curies, is in the vicinity of the electroscope, even a hundred feet or more away with brick and wooden walls intervening, the gold leaves collapse. If you are near the radium, the collapse is fast. If there is no effect, you have no radium. What a game! As much fun as children playing "I spy" with their accompanying shouts of "You're getting hot," "You're getting cold."

Now, in a certain hospital the piece of radium used in medical treatment was carelessly lost. A stupid attendant had thrown it away. Consternation reigned. A potent and remedial agent, scarcer than the proverbial hen's teeth and costing ten thousand dollars, was gone. Then some one suggested, "Let's call a physicist." Yes, he thought he could find it. With an electroscope tucked under his arm and a rubber rod to give it a charge now and then, the game of hide and seek began. In the ash pile, in the waste-paper room, he set up his electroscope and watched its diverged leaves through a telescope. The "scent" was finally picked up. The diverged leaves began to fall very slowly. He moved to a new location outside the hospital. The gold leaves were motionless. He went in exactly the opposite direction. The gold leaves collapsed faster than before. The general direction had become established. (The hounds howl and pull on their leash!) The lost treasure was sure to be found, but there were no secret maps to give its location. The electroscope was moved. The leaves collapsed still faster. Finally the piece of radium was found three blocks away along a river bank in a junk pile. Here was a real adventure. Can Sherlock Holmes equal it? Who mentioned Captain Kidd and Treasure Island?

Exhibit F

Consider the case of Ross, who wrote the following from India after his long struggle to prove that the mosquito transmitted malaria:

> But now, in order to ensure at least definite negative results, redoubled care was taken; almost every cell was examined, even the integument and the legs were not neglected; the evacuations of the insects found in bottles, and the contents of the intestine were scrupulously searched; at the end of the first examination staining reagents were often run through the preparation and it was searched again with care. The work, which was continued from 8 A. M. to 3 or 4 P. M., with a short interval for breakfast, was most exhausting and so blinding that I could scarcely see afterwards, and the difficulty was increased by the fact that my microscope was almost worn out, the screws being rusted with sweat from my hands and forehead, and my only remaining eyepiece being cracked, while swarms of flies persecuted me at their pleasure as I sat with both hands engaged at the instrument. Fortunately my invaluable oil-immersion object glass remained good.
>
> Toward the middle of August I had exhaustively searched numerous grey mosquitoes, and a few brindled ones. The results were absolutely negative; the insects contained nothing whatever. . . . On August 20 I had two remaining insects, both living. Both had been fed on the 16th instant. I had much work to do with other mosquitoes, and was not able to attend to these until late in the afternoon, when my sight had become very fatigued. The seventh dappled-winged mosquito was then successively dissected. Every cell was searched and to my intense disappointment nothing whatever was found, until I came to the insect's stomach. Here, however, just as I was about to abandon the examination, I saw a very delicate circular cell, apparently lying amongst the ordinary cells of the organ, and scarcely distinguishable from them. Almost instinctively I felt that here was something new. On looking further,

another and another and another similar object presented itself. I now focused the lens carefully on one of these, and found that it contained a few minute granules of some black substance, exactly like the pigment of the parasite of malaria. I counted altogether twelve of these cells in the insect, but was so tired with work, and had been so often disappointed before, that I did not at the moment recognize the value of the observation. After mounting the specimen I went home and slept for nearly an hour. On waking, my first thought was that the problem was solved, and so it was.

Is this adventure? Is this romance?

Exhibit G

A professor of forestry recently had an enjoyable experience. Years ago this professor had a lot of fun, according to his own statement, determining what relation the growth rings in tree trunks and the general shape of trees had to wet and dry ground and to rain and drought. Recently the United States sued some lumbermen in Arkansas for cutting timber that did not belong to them. In court the culprits claimed that they had acquired rights by the purchase of claims from early settlers who had lived on the shore of a lake that had dried up about 1840, in which area the cut timber had been. The whole case hinged on whether there had been a lake or not. Well, this professor went down and proved scientifically and conclusively, using cypress trees and old stumps of trees as evidence that there had not been any lake present for at least 150 years. The government got its money all right and, incidentally, just to make the joke complete, the professor got a substantial fee. If there is any man on earth who had a good time, it was this research forester.

Exhibit H

Joseph Henry is one of America's really great figures in science. While professor at Princeton, about 1830, he made important contributions to electromagnetism. To-day, electric sparks are provided for gas ignition in thousands of internal combustion engines by a method discovered by Henry. Two or three dry batteries connected to a coil of about one hundred turns, wrapped around an iron core, thence to the contact inside the cylinder opening and closing does the trick.

In 1837, Henry was in Great Britain and became personally acquainted with England's great physicists. He loved to spend many hours in the company of Michael Faraday, the master experimenter of all time. One day at King's College, Cambridge, Faraday, Wheatstone and Henry tried to get an electric spark from a tiny battery. The Englishman attempted it and failed. Henry, knowing the effect of long wire wrapped around a piece of soft iron, succeeded. It is recorded that Faraday became as wild as a boy and jumping up and down, shouted, "Hooray for the Yankee experiment."

For a scientist, there is no joy like that of working in his chosen field. Oliver Wendell Holmes said, "What have we to do with time but to fill it with labor, to work, to know, to discover and create."

To this the scientist, like the artist, the manufacturer, the business man, the poet, the architect, th enovelist and the clergyman subscribe most heartily. Furthermore, for them it is great fun.

THE MOST INTERESTING WILD ANIMAL IN AMERICA

By EDWARD R. WARREN

LATELY ROOSEVELT GAME NATURALIST, ROOSEVELT WILD LIFE FOREST EXPERIMENT STATION, SYRACUSE, N. Y.

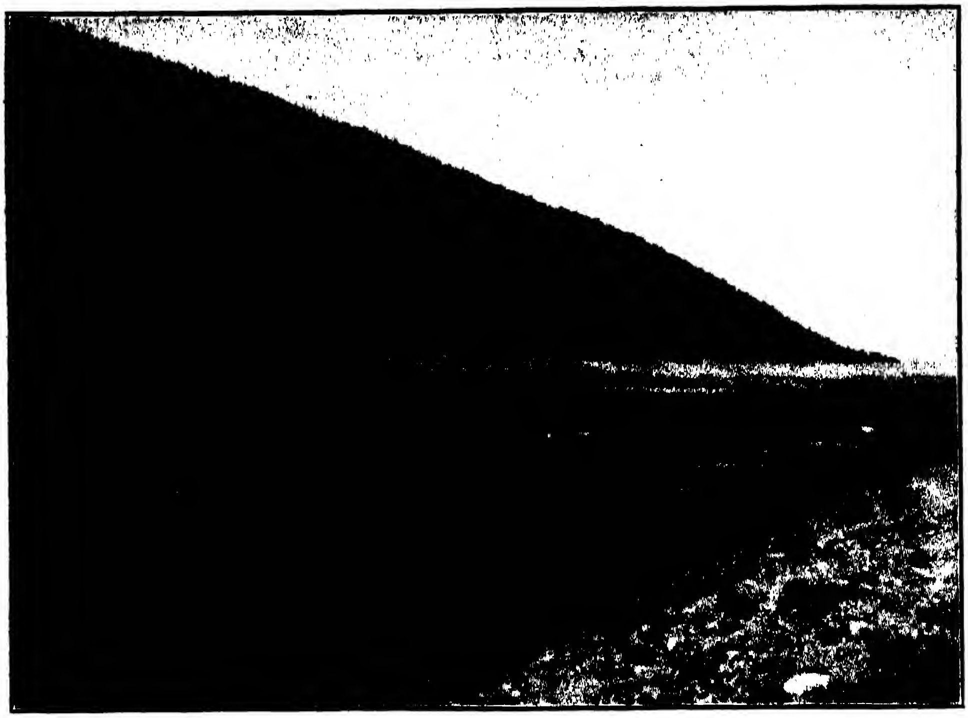
THE most interesting animal in America—at least the beaver is so regarded by many people acquainted with our wild life. And when we take into consideration his intelligent ways, his admirable engineering skill and his quiet, persistent industry, this undoubtedly is true. The beaver was so important a feature in the early history of our country because of its abundance and its highly prized fur that the memory still persists in common geographic names throughout the north; and it has even left its mark in our daily speech, as in the expression, "to work like a beaver." Recently the public has been taking a renewed interest in this fur-bearer, so that we are restocking our wild parks and forests where it has long been exterminated by too intensive trapping. In the Adirondacks, for instance, any one may see the beaver and study his remarkable works along the numberless forest streams of his ancient haunts. In states where the animal was once almost exterminated, strict protection has brought back the beaver population, perhaps increased it over its original numbers.

If you do not know the beaver, imagine a huge, heavily built muskrat, half a foot more than a yard long, with a wide, flat, scaly tail, and of much the same brown color and shape as the muskrat, and you have a fair likeness of a beaver. The hind feet are broad, and webbed like the foot of a goose, with curiously specialized nails on each of the inner toes. These nails are used in combing the fur, as was confirmed by watching captive beavers. The forepaws are smaller, not webbed, and very useful as hands, but are not used in swimming.

The large incisor teeth in each jaw are the tools with which the beaver does his tree cutting. Of an orange color in front, they consist of a hard layer of enamel backed by a softer one of dentine, which is much the thicker, and wears away so much faster that there is always a sharp chisel-edge on the tooth. The teeth are long and rootless, curving far back into the skull and lower jaw, and as they wear away from use they are continually renewed by growth from behind.

It is not its appearance, however, but the things which it does that make the beaver so interesting. The animal is an engineer and builder. It constructs dams, canals and houses, and often does these things in such a manner that it has been credited with almost human intelligence.

When beavers start a new colony on a stream the first thing they do is to build a dam and make a pond, unless the stream happens to be so deep that this is not necessary, or it is so turbulent that dam building is impossible. The first step is to cut brush, usually willow or alder, and lay it on the bottom, butt ends upstream, weighting it down with gravel, mud and stones dug from the bottom above the dam. This is followed by more brush, and then more mud, and so on, until the dam is built to the surface. While, so far as I have had opportunity to observe, the foundation of the dam is usually, if not always,



A BEAVER MEADOW OVERGROWN WITH WILLOWS
PARK COUNTY, COLORADO. E. R. WARREN, PHOTO.

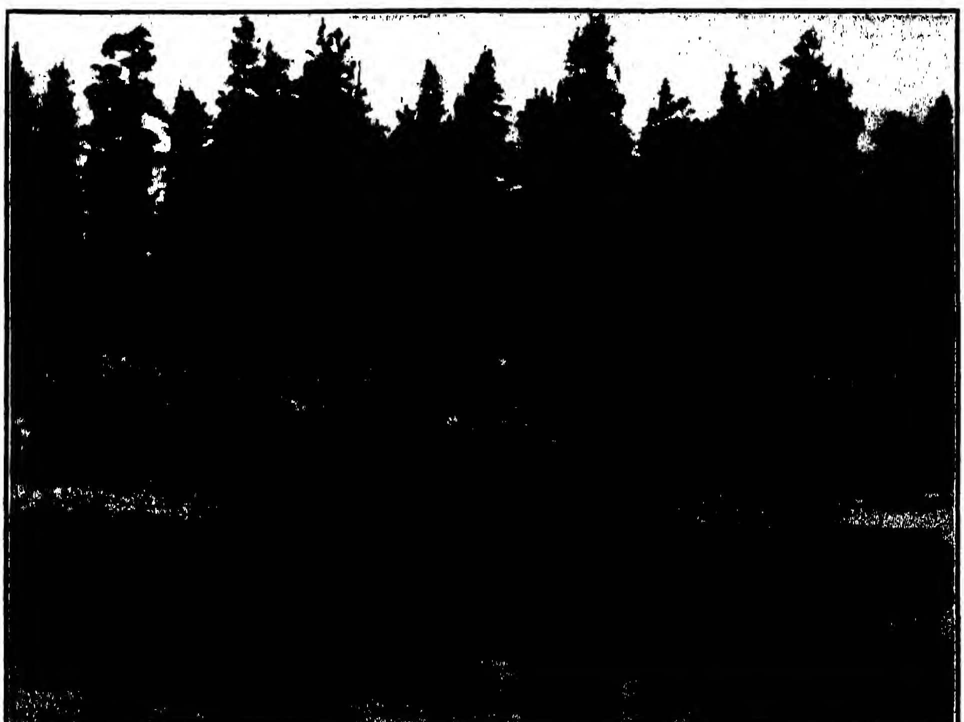
composed of branches laid longitudinally with the current, it would appear that as the structure rises, sticks may also be laid transversely, as the examination of the broken ends of dams seems to show. When the dam is well along toward completion the sticks from which the bark has been eaten are brought to it and deposited in all sorts of positions. Digging material from the bottom leaves a trench of varying width and depth above the dam. At first the water escapes through the numerous interstices, but the stream brings down silt which quickly stops the leaks in the dam. Soon the structure is tight and the pond begins to take form above it. Probably most dams when first built are short and straight, but they are continually repaired and lengthened, and in their final form may be quite crooked. As the water rises in the pond it tends to escape around the ends of the dam, which is extended to stop this, very likely turning up or down stream, as the topography may decide. Then the water rises higher in the pond, and the dam has to be raised. More water goes around the ends and more extension is necessary. It is a continuous process as long as the pond is occupied. Beavers are often credited with building their dams with an upstream curve, the better to withstand the force of the current. True, one often sees dams so constructed, but just as frequently finds them with a downstream curve. The whole thing is a matter of chance, I think, usually the result of extending the ends from time to time. Dams are of all lengths, from tiny ones a foot or so long, up to the one mentioned by Enos Mills, over three thousand feet long; and in height up to fourteen feet, though this is very unusual. The height

of the face of a dam rarely exceeds five feet, and most are considerably lower.

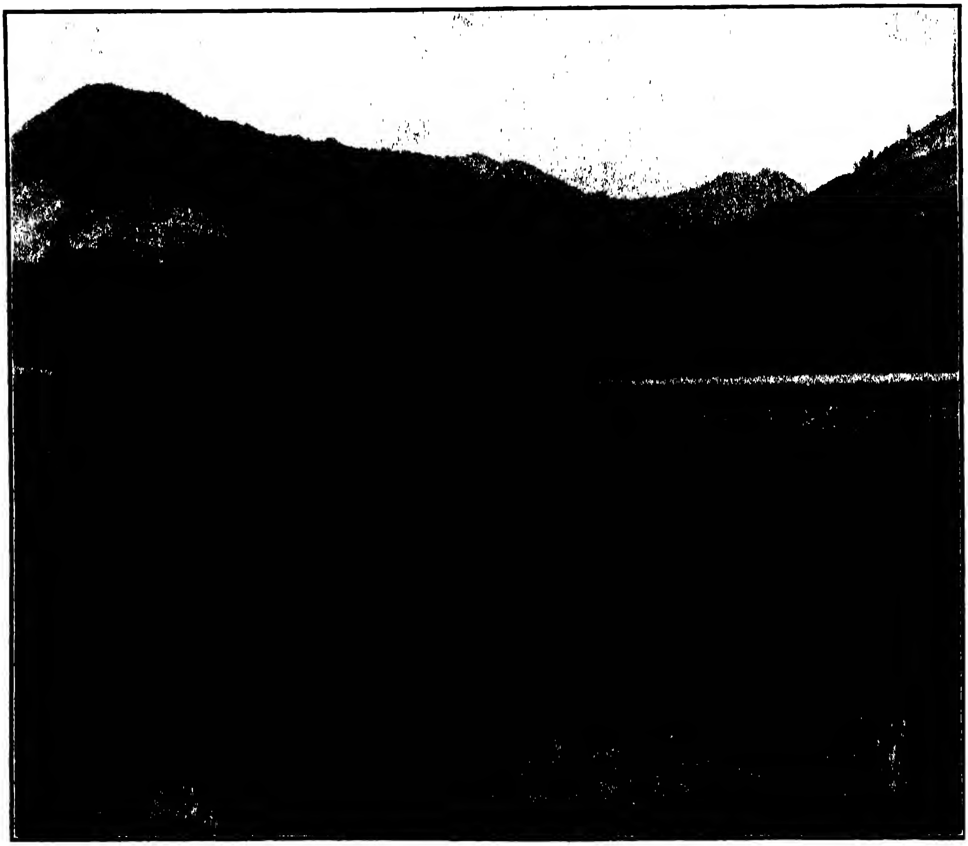
The size of a pond made by a dam depends chiefly on the gradient of the stream. On one with much fall the pond will be short, not infrequently much shorter than the length of the dam. On the other hand, a dam on a stream with a slight fall may back the water up for a long distance. An instance is given of a dam in the Adirondacks, seventy-five feet long, which resulted in a "beaver flow" a mile long.

Often there is a succession of dams and ponds along a stream. These serve various useful purposes: residence, water transportation and travel, and protection of the dams themselves. Water in the lower ponds backed against the dams above protects and strengthens them so that they more easily withstand sudden or unusual strains caused by floods or floating ice. The upper ponds of a series act as reservoirs to hold back flood water and prevent it from damaging the ponds below. Incidentally this is one of the benefits the beaver confers on mankind, the storage of water in the ponds, and the prevention, to some extent at least, of floods. There are instances where beaver ponds made it possible to range cattle where it could not be done before the beavers settled on the stream, there not being sufficient water for the live-stock until they came and conserved it. In certain places beavers have also made more water available for irrigation, and crops have been saved by its use.

When a beaver pond is abandoned by its owners it soon begins to fill with silt and other material brought down by the stream. Very likely this filling has begun before abandonment, may even have been one of its causes. As the water



A BEAVER HOUSE
GUNNISON COUNTY, COLORADO. E. R. WARREN, PHOTO.



A BEAVER DAM AND POND
GUNNISON COUNTY, COLORADO. E. R. WARREN, PHOTO.

drains away, grass and other vegetation begin growing, and after a while instead of wet swampy ground we have a quite dry meadow covered with grass and it may finally become covered with willow bushes. This result may be attained in a very few years, or it may require many. Beaver meadows have furnished hay for pioneers in many places and have doubtless been among the first lands to be taken in the early days of our country. The level ground, comparative freedom from brush or timber and fertile soil rendered them desirable when the land had to be reclaimed from a state of nature by hard work.

A sort of romantic interest seems to be attached to the beaver's house or lodge, the typical form of which, standing in the pond with water all about it, always attracts attention. There are other forms of the lodge which are not so conspicuous. These are built on or against the bank, and are called "bank lodges." Like the dam, the house is built of sticks and mud. When away from the shore or bank it usually has a foundation of some sort, either a small island or a high spot on the pond bottom; or the builders dig mud from the bottom and pile it on the chosen site. In doing this last they at the same time make deeper water about their home. On this foundation mud and brush are piled, somewhat as in building a dam, though the sticks are laid crossing in all directions. As the

structure rises above the surface little or no mud is placed on the central portion. When the house is completed the interstices between the sticks of this part give ventilation.

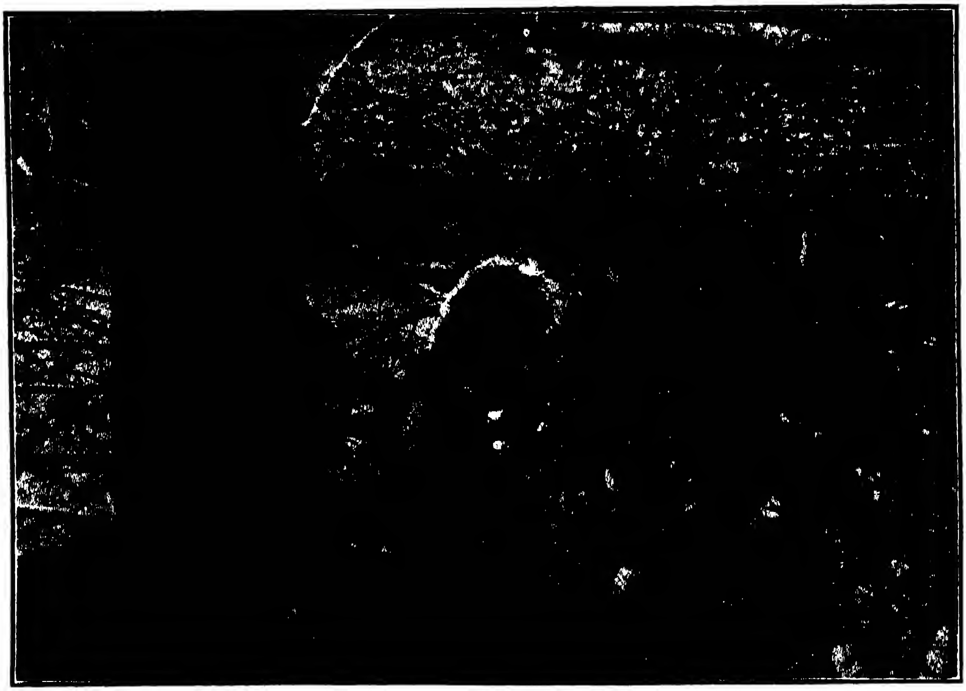
After the lodge is raised to the required height the builders burrow up into it from deep enough below the surface to prevent the entrance being closed by freezing. The sticks are cut away as reached. When the entrance attains a point within the structure a few inches above the water level the chamber or living room is made by a continuation of the burrowing, the interfering sticks being cut away and carried out. The room is twelve to eighteen inches high when completed, and of varying horizontal dimensions. Very large houses may have several unconnected rooms, each with its separate entrance or entrances. There may be only one or two entrances to a house and I have found as many as ten. I have seen a lodge only six feet in diameter, and another 33½ by 39 feet, the largest of which I have any record, and there are all sizes between. The outside of the lodge is often plastered with mud, especially at the advent of cold weather, and good-sized logs and poles are frequently placed on it. I saw a railroad tie lying against the side of one house, and a water-worn piece of two by four on top of another.

Many beavers never build lodges, but live in burrows in the banks, and as a matter of fact the lodge-dwelling beavers are never without burrows to which they can retreat when necessary, if pressed by enemies or the lodge is destroyed. Burrows are anywhere from ten to thirty feet or more long, having their mouths below the surface of the water, but soon rising above water level, and having a room or chamber at or near the end. Some bank lodges appear to be widened parts of burrows roofed over. Others placed against a bank are probably built in much the same manner as those which are out in the pond. I have also found small chambers or rooms in the bank, just below the surface of the ground, roofed with sticks and mud, and large enough for not more than two beavers. These were entered by holes from the water.

The third of the beaver's works is the canal, often a real engineering achievement, more so than either of the others. Canals are usually made to transport food, and may be anywhere from a few feet to more than seven hundred feet long, as in the case of one reported from Montana. They vary from ten inches to two feet deep, and one to four feet wide. They are made by digging the earth along the desired course and piling it on the bank alongside, often doing a very neat job. Frequently a canal has two, or even three levels, the first or lowest deriving the water supply from the pond, the upper level from some other source, such as springs or from swampy ground through which it has been built, or even from another stream. A dam separates the two levels, and the transported material is dragged down over this to the level below.

Beavers depend mostly on the bark of trees for their food, using the inner or cambium layer next the wood by preference, though one finds logs stripped of their bark with none of the outer bark lying about, so that some use must have been made of it. Deciduous trees of almost any available kind, but preferably aspen, are their mainstay, though under certain conditions the bark of conifers is utilized, and here the rough, dry outer bark is sure to be rejected. In summer various shrubs, herbaceous plants and grass are eaten.

To obtain the bark of trees the latter must first be felled, and this is done with the large incisor teeth. Beavers do not cause the trees to fall in any desired direction, though some have claimed that they do, but cut them in the most con-



A COTTONWOOD TREE CUT DOWN BY BEAVER
E. R. WARREN, PHOTO.

venient fashion, and let them fall as they may, usually in the direction in which they happen to lean. Sometimes this woodcutter chips evenly clear round the trunk, and sometimes he cuts all the way through from one side, even with good-sized trees. In cutting, the beaver takes a bite at the upper and lower sides of the notch, and then removes the chip by a sidewise cut and prying action. I have seen chips several inches long taken from large aspens. When felled the branches are cut off and carried away, and the trunk, if not too large, is cut into lengths suitable for transportation, although large logs may be stripped of their bark and left where they fell. As winter approaches the beaver lays in a store of food in the shape of branches and logs, placed in the water convenient to its house or burrow. This store is piled on the bottom, the green wood soon becoming water-logged and remaining in place. Large amounts of this material are sometimes accumulated by a beaver colony. In winter the animals swim under the ice to the foodpile, select a stick and return with it to their home, where they eat the bark, afterward discarding the stick. These discarded sticks often find their way to the dam.

The sticks are carried by taking hold with the teeth near one end and either dragging them alongside or throwing them over the shoulder. Large logs may be rolled to the water by pushing them with the forepaws.

Trees for housebuilding and dams are cut in the same manner as for food, and are often stripped of their bark before being placed in the structure, so that no food is wasted. A tree over three feet in diameter has been known to have been felled by beavers.

Beavers bear their young probably in April or May, four or five being the

A DAM WHICH HAD BEEN CUT THROUGH BY THE STREAM

IT SHOWS THE MIXED ARRANGEMENT OF THE STICKS IN A COMPLETED DAM. GUNNISON COUNTY, COLO. E. R. WARREN, PHOTO.

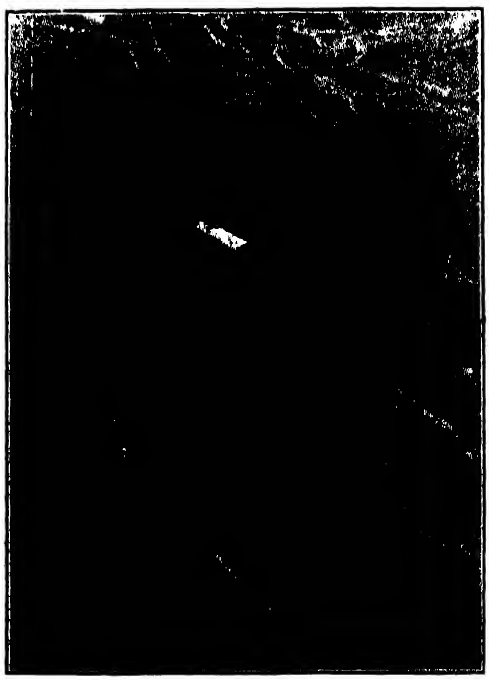
average number. The young are born fully furred and with their eyes open. The young stay with their parents until more than a year old, so that the normal beaver family consists of two adults, the yearlings, and the young of the season or "kits" as they are called.

The average number in such a family is difficult to state. One family which came under my observation consisted of eight, there being three of each of the two ages of young. This may not be far from the average, as enemies doubtless take toll from both old and young. The youngsters are playful, especially in the water. In the lodge they have a whimpering note, somewhat like a young puppy, without any whining tone.

It goes without saying that the beaver is an expert swimmer, using the broadly webbed hind feet as propellers, and occasionally sculling with the tail, which is also used as a rudder, which is perhaps its usual function in the water. The animal is able to swim under water several minutes at a time. It is an easy diver, and can slip into the water or submerge very quietly if it so desires, or it may alarm the whole neighborhood with a resounding whack of its tail as it goes down. A beaver has been seen to swim in daytime for an hour or more, frequently diving with a slap of its tail apparently in sport, though this tail slapping is commonly supposed to be a danger signal.

Naturally, the beaver has its enemies. Man, of course, is the worst. Coyotes, wolves, cougars, lynxes, bobcats, bears, all like a taste of beaver meat when they can get it. Usually the victims are surprised on land, but occasionally, no doubt, one is taken when in shallow water.

Ever since the American continent was settled the beaver has been trapped for its fur, at first mainly for the purpose of obtaining material for making hats. Even now, the formal "stovepipe" is often referred to as a beaver. The manufacture of hatter's silk, and the substitution of the fur of the South



A BEAVER ON THE DAM

TAKEN IN THE DAYTIME IN THE YELLOWSTONE NATIONAL PARK. PHOTO BY E. R. WARREN, PUBLISHED BY COURTESY OF THE ROOSEVELT WILD LIFE FOREST EXPERIMENT STATION.

A COTTONWOOD TREE PARTLY CUT BY BEAVER

THE RULE LYING ON THE STUMP IS TWO FEET LONG. TRINCHERA ESTATE, COLO. E. R. WARREN, PHOTO.

American nutria for the same purpose, put an end to this use. This perhaps gave the animal a short respite from the trappers. But the fur is of too fine a quality not to be utilized, and there has always been a demand for it. At the present day it brings a high price in the market. The persecution by trappers resulted in the beaver's extermination over a great part of its range, and probably nowhere, except possibly in a few favored localities under strict protection, could it be found in anything like its former abundance. The Yellowstone National Park is a splendid example of the result of local protection. Here the animals are flourishing, increasing greatly in numbers, and often to be seen swimming in their ponds or going ashore after food, quite indifferent to the silent spectators who may be standing close by watching every movement with the greatest interest. It was my belief during the two summers I spent studying the beavers near Camp Roosevelt in the park that these were the animals of most interest to the tourist. They all wanted to know about them and to see them. It

was here that I made a somewhat extended study of the animal and its works, the results of which are contained in the Roosevelt Wild Life Annals, "The Beaver in the Yellowstone National Park."[1]

Wherever protected beavers increase rapidly. Sometimes too rapidly, one might think. Once exterminated in the Adirondacks, a few from Canada and the Yellowstone Park were liberated there some twenty years ago. They are now numbered by thousands, and it is a question whether their numbers should not be reduced locally to prevent further damage to valued trees or where too much woodland is being killed by flooding. Such control should be done carefully and under competent supervision. Unrestricted trapping would soon reduce the beaver population to the vanishing point; but, on the other hand, under complete protection they may become so numerous as to be their own worst enemy, through depletion of the available food supply. This is something which seems quite possible in the Yellowstone. A reasonable number of beaver should be permanently maintained in such wilderness regions as the Adirondack for the education of the large numbers of campers and visitors who are sincerely interested in all forms of wild life, as well as for the legitimate taking of valuable fur from time to time, according to conditions.

During the past few years attempts have been made at "Beaver Farming," raising beavers in confinement for commercial purposes. The pioneers in this business will probably make their profits from animals sold for breeding and stocking rather than from the fur marketed. Because of the aquatic habits of the animal and the nature of its food the securing of suitable places for such enterprises may be difficult, and it will be some time before many pelts taken from captive beavers come on the market. At the same time the attempts to raise beavers in captivity will no doubt give us much information as to their breeding habits and the care of the young; indeed, they have already done so.

[1] See also "The Beaver: Its Work and Its Ways," The Williams and Wilkins Company, Baltimore.

A VISIT TO THE MUD-VOLCANOES OF TURBACO, COLOMBIA[1]

By ALBERT C. SMITH
LEVERETT, MASSACHUSETTS

Of all the features of lowland Colombia which hold interest for the scientist, none is more deserving of a visit than the mud-volcanoes of Turbaco. Yet this unusual phenomenon has seldom been witnessed by others than natives of the region. Alexander Humboldt, one of the first scientists to realize the potentialities of exploration in tropical America, visited the volcanoes, and through his pen alone have we a description of them.

It was the good fortune of a botanical expedition which recently visited Colombia to spend some time at Turbaco, a village near which the mud-volcanoes are situated. Although our primary objective was to collect the plants of the neighborhood, we welcomed the opportunity to visit a scene which, perhaps, no foreigner had witnessed since Humboldt traversed the region. We also looked forward to enriching our botanical treasures, since plants from the territory near the volcanoes are known only from Humboldt's collections.

So we set out from the town of Turbaco, which lies among beautiful roll-

A GENERAL VIEW OF THE VOLCANO FIELD

It can be seen that the slope of the cones is very gradual. Down the sides of some of them the liquid mud is flowing, having been forced from the craters by the rising gases.

[1] A visit made in November, 1926, by the Killip-Smith Expedition to Colombia, under the auspices of the Smithsonian Institution, the New York Botanical Garden, Gray Herbarium, and the Arnold Arboretum. The photographs are by Mr. Ellsworth P. Killip.

A CLOSER VIEW OF TWO CRATERS

THE ONE ON THE LEFT IS NOT ELEVATED AT ALL FROM THE SURFACE OF THE FIELD, BUT STILL IT FORCES OUT MUD. IN THE FOREGROUND THE MUD HAS HARDENED AND CAKED. IN MANY PLACES THE SURFACE IS YIELDING, AND AS DANGEROUS AS QUICKSAND.

ing hills a few miles from the north coast of Colombia. Of all the villages which Humboldt visited in South America, none has he eulogized as Turbaco, praising its climate, its beauty and the charm and kindness of the inhabitants. Continuing, he describes his trip to the volcanoes:

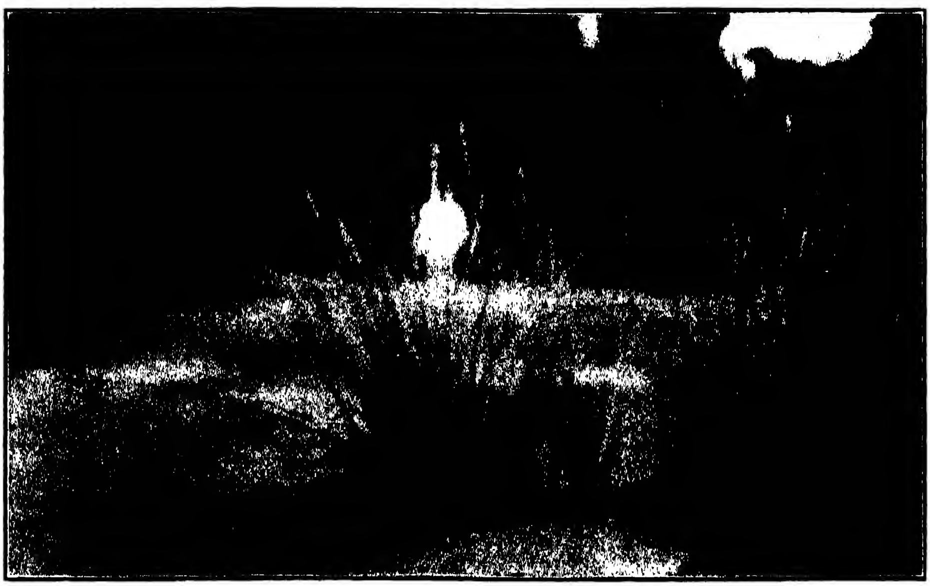
The Indians of Turbaco, who accompanied us on our herbalizations, often spoke to us of a marshy country, situate amongst a forest of palm trees, and called by the Creoles the little volcanoes, *los Volcancitos.* They related that, according to a tradition still existing among them, this spot had formerly been in flames; but that a very pious man, vicar of the village, had succeeded by his frequent aspersions of holy water in extinguishing the subterranean fire. They added that, since this time, the fiery volcano had become a watery volcano, *volcan de agua.* . . Without giving any credit to the existence of an extent of country in a former state of ignition, we were conducted by the Indians to the Volcancitos de Turbaco; and this excursion made us acquainted with phenomena much more important than any we could have expected. . . .

In the center of a vast plain, bordered by bromelia karatas, are eighteen or twenty small cones, in height not above seven or eight meters. These cones are formed of a blackish gray clay, and have an opening at their summits filled with water. On approaching these small craters a hollow but very distinct sound is heard at intervals, fifteen or eighteen seconds previous to the disengagement of a great quantity of air. The force with which this air rises above the surface of the water may lead us to suppose that it undergoes great pressure in the bowels of the Earth. I generally reckoned five explosions in two minutes; and this phenomenon is often attended with a muddy ejection. The Indians assured us that the forms of the cones undergo no visible change in a great number of years; but the ascending force of the gas and the frequency of the explosions appear to vary according to the seasons. I found by analyses made by means both of nitrous gas and of phosphorus, that the disengaged air scarcely contains a thousandth part of oxygen. It is azotic gas, much more pure than that which is generally prepared in our laboratories.[2]

[2] From "Researches concerning the Institutions and Monuments of the Ancient Inhabitants of America," by Alexander Humboldt. Vol. II, p. 95.

REALISTIC MINIATURE VOLCANOES

THESE TWO CRATERS ARE OF THE TYPE WHICH HAVE STEEP SIDES AND SMALL MOUTHS. THEY ARE IRREGULAR IN ERUPTION, BUT WHEN A DISCHARGE DOES TAKE PLACE IT IS MORE FORCEFUL THAN IN THE MORE PREDOMINANT TYPE.



THE MOUTH OF A FUMAROLE

SOME OF THE SEDGES SEEM TO THRIVE IN THE LIQUID MUD, GROWING ON THE CRESTS OF THE VOLCANOES.

A SPECIES OF ACHRIS WHICH SURROUNDS THE FIELD

THE TOUGH FIBERS OF MANY SPECIES ALLIED TO THIS ARE USED BY THE COLOMBIANS FOR MAKING ROPE.

It was with this description in mind that we traversed the muddy road from Turbaco. The vegetation of the region is made up of typical lowland thickets, overgrown with creepers and vines, often covered with brilliant morning glories. Occasionally huge trees rise out of the jungle, but these are exceptional. Palms occur in groves, but are not common.

In the midst of this tropic vegetation is the level space which forms the volcano field. The plain is rectangular in shape, about two hundred by five hundred yards. The soil of this region is a dark brown clay, which varies in consistency from a soft mud to a hard, caked surface. The area is more or less divided into three sections, which are separated from one another by irregular clumps of sedges. The entire field is bordered by a growth of a species of Achris (the "bromelia karatas" which Humboldt mentions).

It is possible that the number of craters varies from time to time, but at present there are between fifty and sixty active ones. Their dimensions as given by Humboldt are considerably exaggerated, due either to a change which has taken place in the last hundred years, or to the enthusiastic imagination of the old traveler. At any rate, at present the cones are elevated no more than three or four feet above the surface of the field, and many of them are even less.

In general there are two types of craters, the most predominant type being characterized by gradually sloping sides and a wide mouth, which varies in diameter from one to five feet. The cold and creamy liquid which fills these craters is usually continuous in its bubbling; it sometimes overflows the rim of the fumarole and runs down the sides, to harden in the glaring sun. The remaining volcanoes generally have much steeper crowns of mud and smaller mouths, sometimes only two or three inches in diameter. This type is often inactive, but occasional forceful eruptions eject streams of mud several inches

A THICKET COVERED WITH MORNING GLORIES

THE VEGETATION OF LOWLAND COLOMBIA IS PREDOMINATED BY THESE VIRILE VINES WITH THEIR MANY-HUED FLOWERS. IN THE REGION OF THE MUD-VOLCANOES THEY ARE PARTICULARLY WELL DEVELOPED.

into the air. The only sound which accompanies this disengagement of gas is a faint bubbling, as that of boiling water. One's first thought on viewing the liquid in the craters is that it is boiling, but examination proves that it is cold, and that the commotion is caused by gas passing through it.

Mud-volcanoes, or air-volcanoes, as they are often known, occur in several regions of the globe. There are two types: first, where the movement is caused by gaseous discharges, and second, where the active agent is steam. Those of Turbaco are an illustration of the former type. The cones themselves are formed by an accumulation of fine saline mud which is given out, with various gases, from a crater in the center. Gradually these outpourings of mud harden until a perfect miniature volcano is formed. Sometimes a hard tropic rain will wash down the small cones and spread the material over the ground, but new gas bubbles appear through the mud, and hence new cones are formed.

Thus it is seen that the origin of the gas is quite deep in the ground, and that by some chemical method it is freed from subterranean strata. Gases which are associated with mud-volcanoes are chiefly hydrocarbons, with more or less carburetted and sulphuretted hydrogen and nitrogen.

An analysis of the mud from the volcanoes of Turbaco shows little which is exceptional. The U. S. Bureau of Soils finds it to consist essentially of quartz and colloids (both as coatings on grains and as aggregates); with lesser amounts of muscovite, and very small amounts of biotite, tourmaline, orthoclase, calcite, and traces of zircon. (An analysis by Mr. W. H. Fry.)

SIR ISAAC NEWTON ON GRAVITATION

By Professor FLORIAN CAJORI
UNIVERSITY OF CALIFORNIA

Of all the scientific men of the world few, if any, have surpassed Sir Isaac Newton in the depth and importance of their discoveries. It is therefore very singular that some writers describing the achievements of Newton resort to exaggeration and to legend.

In the room in which Newton was born there is a tablet bearing Alexander Pope's lines,

Nature and nature's laws lay hid in night
God said, "Let Newton be" and all was light.

This statement indicates Pope's cleverness, but it lacks sincerity. "Nature's laws lay hid in night" ignores Kepler, who exercised extraordinary mathematical keenness in taking Tycho Brahe's observations on the positions of planets and from them deducing the three famous "Kepler's laws." The first of these laws states that the planets move in elliptical orbits having the sun at one of the foci; the second, that the straight line joining any planet with the sun moves over equal areas of space in equal periods of time; the third, that the squares of the times in which any two planets complete a revolution round the sun are proportional to the cubes of their mean distances from it.

Newton's earliest studies connected with Kepler's laws and with Kepler's book on optics. Had there been no Kepler there could have been no Newton as we know him; Newton would have been compelled to begin research further back and to have spent much effort on preliminaries. Newton's law of gravitation consigned to the scrap heap Descartes' theory of planetary mechanics, with its famous "vortices," and yet the general concept of Descartes was a philosophical contribution of prime importance to Newton. We mean the concept that celestial motions should be explained on mechanical principles and not on the primitive hypothesis of animism, according to which the planets are moved by spirits, benign or evil. The phrase "hid in night" also forgets that there was a Copernicus, that there was a Greek by the name of Aristarchus who two thousand years before Copernicus taught what is known as the "Copernican system." Again, the phrase forgets that the history of science exhibits torch-bearers all the way down the centuries, some torches, to be sure, being more brilliant than others.

The latter part of Pope's couplet claims too much. Like the first part, it is noteworthy only for the extravagance of its untruth. Of no man can it be said that, due to him, "all was light," for this implies that the end of questioning nature was reached, that there was no room for a Laplace and a Herschel, for a Newcomb and an Einstein. The highest poetry is not poetry of exaggeration, of gross distortion; the highest poetry is poetry of truth.

Other writers on Newton have indulged in the promulgation of legend; prose writers as well as poets have been guilty of that practice. Particularly is this true when writing about Newton's discovery of the law of gravitation. It is well known that about twenty years intervened between his first computation and his final announcement of the law. A vital question in the scientific career

of Newton is, what was the cause of this long delay? Here it appears as though the fates had conspired to distort the facts, to misrepresent the deep scientific questions which perplexed Newton, to ignore the intense intellectual struggle which alone could remove the difficulties which his profound mind saw but which lesser minds had overlooked. In the popular erroneous account of the progress of Newton's great discovery there is no room for such an intellectual struggle. His delay, so it is claimed, was due to a wrong value of the radius of the earth. When twenty years later the correct value was announced to him, a short computation revealed the law. How simple is this legendary story. The legendary account minifies the real achievement of Newton.

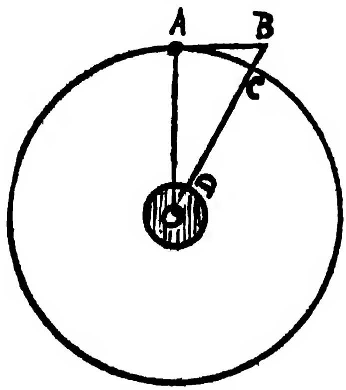
Newton's Computation of 1666

Let us state the facts regarding which there is general agreement. Newton had taken the degree of B.A. at Trinity College, Cambridge, early in 1665. He was then twenty-three years old. A dreadful plague broke out, the college was closed, and Newton returned to the country where he was born, in Lincolnshire, where he remained the larger part of nearly two years. Amusements so common in our day—the phonograph, cinema, radio, automobile—were unknown in his day. Thus a person inclined to silent contemplation was free to indulge in that luxury without undue distraction. Newton's mind dwelled upon problems in mathematics and he developed, as his notebooks indicate, the first notions of "fluxions," or what is now called the differential calculus. His mind dwelled also upon the cause of planetary motion, which had become a common topic of discussion among astronomers after Kepler had discovered his three laws about half a century earlier. Kepler's laws were purely descriptive in character. They were three isolated statements telling *how*, but not *why*. It was natural for scientists to search for an underlying and unifying principle. Kepler himself came very near the truth, for he realized that attraction between two bodies was mutual and proportional to the mass, and varied with the distance, but the exact law of variation escaped him. He supposed it to be the inverse distance instead of the inverse square of the distance. Newton deduced the law of inverse squares from Kepler's third law, by a process of mathematical analysis, a result which was independently reached by others. The curious reader may ask, what more remained to be done, to establish the law of gravitation? If this law was found to be a consequence of Kepler's third law of planetary motion, why not rest upon the oars and rejoice? But the matter was not quite so simple. In the first place, there remained reasonable doubt as to the accuracy of Kepler's third law. It had been established by induction. It was deduced from data on the positions of planets at successive periods of time. Observations are only approximate, hence the proof of a law is only approximate. Had the conclusions of Kepler been checked with sufficient care to warrant implicit acceptance? They had not.

In the second place, how should distance be measured in estimating the attraction between the sun and a planet? Should it be measured from surface to surface? Or from center to center, or from a point below the surface a third or half way to the center? No one had shown that one of these modes of measuring the distance was correct and all others were wrong. The planets were so far apart that a slight error in the terminal points of a distance does not matter much. But how would it be with large bodies in closer proximity? No one had settled the question. Evidently

scientists were justified in exercising skepticism.

So Newton, whose thoughts were not distracted in the quiet of his country retreat by radio or cinema, permitted his mind to dwell upon this interesting problem. Tradition has it that he saw an apple fall from a tree at his boyhood home and that this incident initiated a train of thought on gravitational attraction. No one can prove or disprove the truth of this story. There is nothing inherently improbable in it. However, at this time Newton's thoughts began to dwell upon the earth's attraction for the moon. Was the moon attracted to the earth by a force which varied according to the law of the inverse square of its distance from the earth? If so, can this be checked by mathematical computation? A simple process of computation was published twenty-one years later in Newton's "Principia." Presumably this is in substance the same process of reasoning as that followed by him in the computation of 1666. If in



some way he could find the distance BC (see figure) through which the moon falls toward the earth in a short period of time (say, a second), he could compute the distance a body, in the same period of time, would fall from rest at D, on the surface of the earth, according to the law of gravitation. The computed value could be then compared with the experimental value. It should be premised that if the moon moving at A were not attracted by the earth, it would travel in a straight line a distance AB in the time considered. But the earth pulls the moon down a distance BC, prevents the moon from "going off on a tangent," and causes it to move in a curved path. Newton had the means of computing BC. He knew the distance of the moon from the center of the earth to be very nearly sixty times the radius of the earth. He knew that the moon revolves around the earth once in twenty-seven days, seven hours and forty-three minutes. Hence he could compute the distance AC the moon travels in its orbit in a second, and also by geometry, the fall BC. Now would come the crucial test. If a body falls a distance BC when as remote as the moon, how far would it fall if it were at D, on the surface of the earth, sixty times nearer to the earth's center? If the law of attraction according to the inverse square of the distance is true, the fall at D should be sixty times sixty, or 3,600 times greater. But we know from actual measurement that a body falls from rest on the earth's surface nearly 16.1 feet in a second. Are the computed and experimental values the same? We do not know the details of Newton's computation in the year 1666. We do not know how accurately the computed and experimental values agreed. But we do know that about 1887 the astronomer J. C. Adams discovered in the Portsmouth Collection of Newtonian manuscripts a sheet in Newton's own handwriting and containing a reference to this computation, to the effect that in 1666 Newton "found them answer pretty nearly." Yet Newton delayed the announcement of the law of gravitation for twenty years. Why?

Legendary Account of the Discovery of Gravitation

When, after his death, Newton's career came to be surveyed, the cause of the twenty years' delay demanded explanation. Newton's letters to Halley, relating to a controversy between Newton and Robert Hooke on the priority of advancing the law of inverse squares in gravitational attraction, were not published at that time and were not generally known. One of the experimental data used in the computation of 1666 was the radius of the earth, by which the length of the moon's orbit was obtained. A gross error in the size of the earth would spoil the computation. Before Newton, there were varying estimates for the size of the earth, some fairly accurate, others far remote from the truth. According to the legendary account, Newton, by a tragedy of misfortune, used too small a value for the size of the earth. This popular account rests partly on statements of old age with its defective memory; the more correct account rests, as we shall see, upon statements written by Newton himself and made when he was in the prime of life. The popular version is due mainly to Henry Pemberton, who in 1728, the year after Newton's death, published "A View of Sir Isaac Newton's Philosophy." He states in the preface:

> It was in the very last years of Sir Isaac's life, that I had the honour of his acquaintance . . . he engaged me to take care of the new edition he was about making of his Principia. . . . Though his memory was much decayed, I found he perfectly understood his own writings. . . .
>
> Supposing therefore the power of gravity, when extended to the moon, to decrease in the same manner, he computed whether the force would be sufficient to keep the moon in her orbit. In this computation, being absent from books, he took the common estimate in use among geographers and seamen, before Norwood measured the earth, that 60 English miles were contained in one degree of latitude on the surface of the earth. But as this is a very faulty supposition, each degree containing about 69½ of our miles, his computation did not answer expectation; whence he concluded that some other cause must at least join with the action of the power of gravity on the moon. On this account he laid aside for that time any further thoughts upon this matter.

This explanation sounds very plausible.

The next step in the growth of this legend was the dramatization of Newton's behavior when Picard's exact earth-measurement, given out in 1671, became known to him. It is said that in repeating the earth-moon computation he was taken with such intense emotion that, to carry it to a finish, he had to secure the assistance of a friend. As a poet puts it:

> . . . his hand shook
> And dropped the pencil. "Work it out for me,"
> He cried to those around him; for the weight
> Of that celestial music overwhelmed him.

These seemingly plausible and poetic accounts do not rest upon sound foundation. The story of Newton's supposed intense emotion first appeared in 1804 in Dr. Robison's "Mechanical Philosophy," about one hundred and twenty years after Newton announced his great discovery.

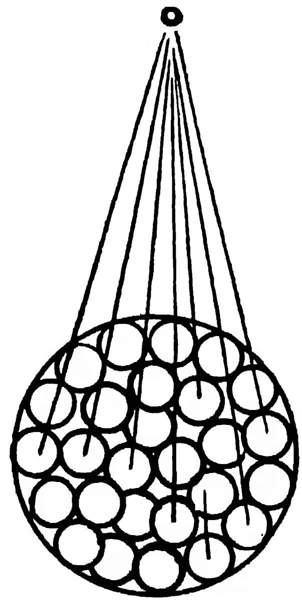
As to Pemberton's account, we have made an intensive study of it and have found it in conflict with certain historical facts and with Newton's own written statements. Pemberton says that Newton's computation of 1666 "did not answer expectation"; Newton himself said that he "found them answer pretty nearly." Pemberton refers to the size of the earth as estimated by English seamen, but he is mistaken as to the kind of miles used by seamen. They commonly took the degree of latitude to be sixty miles, not English statute miles of 5,280 feet each, as Pemberton claimed, but miles of 5,000 feet each. Newton himself, in his "Principia" used miles of 5,000 feet each. If in 1666 Newton

took, as Pemberton claims, the seamen's estimate of a degree, he used sixty miles of 5,000 feet each, when he should have used nearly 69.1 English statute miles of 5,280 feet each; his computed value would have differed from the experimental value by as much as 18 per cent. and he could not possibly have "found them answer pretty nearly." Such an expression of agreement would have been absurd. Again, Pemberton says that Newton was "absent from books," but Newton's account of expenses during 1665 and 1666 shows that he purchased "Gunter's Book and Sector." Most probably this was one of the books containing a description of the sector and cross-staff, wherein Gunter urges the adoption of Snell's careful measurements of the earth, made in the year 1617, which were equivalent to sixty-six and two-thirds English statute miles per degree. Most probably this was the value that Newton used in 1666. The answer would have been within 4 per cent. of the truth and might well have elicited the remark that he "found them answer pretty nearly." The rôle of this copy of Gunter's book in Newton's great discovery has been hitherto overlooked. Richard Norwood in 1636 had measured the distance between London and York and obtained a still more accurate value for the size of the earth. We do not know that in 1666 Newton was familiar with that estimate; its use would have reduced the error far below 4 per cent. We see that Pemberton lays all Newton's troubles relating to gravitation to his use of a wrong value for the size of the earth; Newton nowhere makes such a statement. He nowhere ascribes his delay to a wrong value for the earth's radius. But he does point to theoretical difficulties which at first he was not able to overcome.

Thus it appears that the popular story relating to Newton and gravitation and the cause of his delay in publishing the law is a gross distortion of the facts.

A Necessary Step in Proving the Law of Gravitation

What was the nature of Newton's difficulty? Why did he delay for twenty years the announcement of the law of gravitation? It was a difficulty in the theory which less profound thinkers had completely overlooked. It was the problem, how a homogeneous sphere attracts an outside particle (see figure).



In applying the gravitational hypothesis, should the distance be measured from the outside particle to the center of the earth, or to a point nearer or farther than the center? Primarily the force of gravitation acts between minute parts of bodies. Each small particle of the earth attracts the outside particle. These attractions are not all of the same intensity, because some particles are at a greater distance from the outside particle than others. Moreover, the directions of these attractions vary. It is a difficult mathematical problem to find the resultant of all these forces. It is a

subtle problem in the integral calculus. Nor is it easy to anticipate just what the result will be. Newton solved it in the year 1684. The result came out much simpler and more beautiful than he had expected. The distance must be measured from the *center* of the earth to the outside particle. Robert Hooke, who claimed the law of gravitation as his own prior discovery, had assumed all this without demonstration. In a letter dated June 20, 1686, Newton wrote to Halley: "There is so strong an objection against the accurateness of this proportion, that without my demonstrations to which Mr. Hooke is yet a stranger, it can not be believed by a judicious philosopher to be anywhere accurate." His theorem is proved in his "Principia," Book I, Proposition 71. Relating this important theorem, Dr. J. W. L. Glaisher wrote in 1888 at the bicentenary celebration of the publication of the "Principia": "No sooner had Newton proved this superb theorem —and we know from his own words that he had no expectation of so beautiful a result till it emerged from his mathematical investigation—than all the mechanism of the universe at once lay spread before him."

PUBLICATION OF THE "PRINCIPIA"

Newton's intellectual interests were manifold. He worked in the fields of gravitation, optics, mechanics, comets, algebra, geometry, infinite series, fluxions, chemistry, biblical criticism—in fact in almost any intellectual realm which happened to strike his fancy. What circumstance directed him toward the preparation of the "Principia"? The answer to this important question involves the astronomer, Edmund Halley, who was the son of a soap manufacturer and was fourteen years younger than Newton. He had been a student at Queens College at Oxford. Interested in astronomy from boyhood, he went at the age of twenty to St. Helena to observe the positions of fixed stars in the southern heavens. Like other astronomers he was meditating on the problem of gravitation; he had come to admire Newton's powers, and in August, 1684, he went from London to Cambridge to ask Newton a question. He desired to know what would be the curve described by a planet on the supposition that gravity diminished as the square of the distance. Newton was able to answer instantaneously that the curve was an "ellipse," for some years earlier, in 1679, this question had arisen in his correspondence with Hooke and had been solved by him. Halley naturally desired to see the proof, but Newton, not being able to find his notes, promised to send the proof later. He worked it out again and, extending his researches, was able within three months to send Halley a manuscript containing eleven propositions on central forces. Halley saw the importance of the results and at once paid a second visit to Cambridge, to confer with Newton on the matter. Halley extracted from him the promise that he would communicate his researches on this subject to the Royal Society, of which he was a member. At a meeting of December 10, 1684, Halley gave an account of Newton's treatise on motion. Fortunately Newton continued work on this topic. About this time, or soon after, he proved the fundamental theorem on the attraction of a sphere upon an outside particle, that subtle problem which before this had baffled his best efforts. On April 28, 1685, the first book of the "Principia" was sent to the Royal Society. Newton was now working with an intensity of effort and a brilliancy of success seldom, if ever, equaled in the history of science. The second book of the "Principia" was finished in the summer of 1685. In March, 1687, Newton sent Halley the

second together with the third and final book of the "Principia."

At this time two events threatened to thwart the publication of the "Principia"; one was controversial in nature, the other financial. No sooner was Newton's first instalment presented to the Royal Society than Robert Hooke entered a claim of priority, the claim that the law of gravitation was his own earlier discovery and that Newton was indebted to him for it. Newton, who was always sensitive to criticism, was greatly disturbed and wrote Halley letters denying any such indebtedness and showing that his gravitational research was much earlier than that of Hooke. There is no doubt that Hooke had arrived at an *hypothesis* regarding gravitation, as had also Wren and Halley, but Newton was the only one possessing the penetrating genius which changed the hypothesis into a certainty. Newton also wrote Halley that he wished to withdraw from publication the third book of the "Principia," the very book which contains the application of abstract theory to the motions of the members of the planetary system, to the shape of the earth and to the tides. The tact and devotion of Halley saved the day; he succeeded in pacifying Newton so that the publication of the entire work was allowed to proceed.

As early as May 19, 1686, the Royal Society ordered that Newton's book be printed. One difficulty was encountered in carrying out this order; there was no money in the treasury! The society was issuing a book on the history of fishes, which had absorbed the available funds. Thus a book which does not in the least interest scientific men of the present day stood in the way of perhaps the greatest scientific book ever written. Science progress was on the verge of a real catastrophe. A tragedy of misfortune was impending. A second time Halley came to the rescue. The son of well-to-do parents, Halley had been accustomed in his earlier career to spend money freely. Although at this time he was less prosperous financially and, moreover, had a family to support, nevertheless he assumed the entire financial burden; as a mathematician and astronomer of real insight, he was fully able to recognize and admire the great merits of Newton's book. The second calamity was averted.

The reception of Newton's gravitational theory was not immediate, not even in England, or even in Cambridge. The "Principia" was not food for babes. An understanding of it called for mathematical training of a high order, and willingness to devote midnight oil to its mastery. The older and rival "theory of vortices" of Descartes, according to which the planets are carried around in their course, as is a chip of wood in an eddy of water, presented a picture at once comprehensible and satisfying to the uncritical mind. For about forty years after the publication of Newton's "Principia" in 1687, the Cartesian system maintained a foothold in England. Voltaire, who attended Newton's funeral, declared that at his death Newton had not above twenty followers in England. On the continent the vortices of Descartes were still in great favor, but by the middle of the eighteenth century they were being rapidly displaced by the Newtonian system. Since that time the celestial mechanics of Newton has held undisputed sway. Not even the relativity theory of Albert Einstein can claim to have upset it. That theory, if true, constitutes a generalization of Newton's system, not an overthrow of it.

THE RADIOACTIVE ELEMENTS

By Dr. L. R. KOLLER

RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

The element radium, more than any of the other known elements which make up our world, has served to give mankind a knowledge of the nature of these elements and of the history of the world which they form. It has given us an insight into the structure of the atom and of the relations between the atoms of different elements. This has come about in two ways. First of all, through observation of the disintegration processes which the radioactive elements undergo; and secondly, by using as probes the swift alpha particles emitted by radium. These are shot out at a speed nearly one tenth of that of light and penetrate into the very hearts of atoms, and by their behavior give us much information regarding their structure. In addition, radium is making a large contribution to the physical welfare of man in the treatment of disease.

The radioactive elements manifest their presence in a number of different ways. They cause certain substances, such as zinc sulfide, to fluoresce in the dark. They blacken a photographic plate. Their most convenient manifestation, however, for both quantitative and qualitative scientific work is their ability to ionize gases. This is indicated by the rate at which an electroscope is discharged in the presence of radioactive material.

The characteristic that differentiates the radioactive elements from the other elements is their spontaneous disintegration. Before discussing disintegration, however, a few words concerning the structure of the atom will not be amiss.

According to the very earliest ideas matter consisted of small discrete particles or atoms. These atoms were supposed to be the very smallest particles that could exist; the particles that one obtained by subdividing matter until it could be subdivided no further. This was the generally prevailing view until the discovery of the radioactive elements. There had been other theories, but there was no evidence of an experimental nature to support them. With the discovery of the radioactive elements came the knowledge that the atoms were not the ultimate indivisible units of matter, but that they themselves could be split up into smaller units, namely, protons and electrons.

The electron is one of the ultimate constituents of all matter. It is the unit charge of negative electricity. Its presence was first shown in a conclusive manner by Sir J. J. Thomson in 1897. He showed that the so-called cathode rays really consisted of a stream of particles smaller than atoms which were always of the same size, regardless of how they were produced or from what they were produced.

We now know the mass and charge of the electron to a high degree of accuracy due to the measurements made by Professor R. A. Millikan.

The other constituent of all matter is the proton or positive charge of electricity. All the known kinds of matter are made up of these two kinds of building material, their differences being solely due to the relative numbers and arrangements of the protons and electrons.

Through the work of Sir J. J. Thomson, Sir Ernest Rutherford, Niels Bohr and many others, we have a very de-

tailed picture of this structure. Each atom consists of a nucleus of positive electricity in the center surrounded by one or more electrons rotating about it in elliptical orbits. The simplest atom of all is the hydrogen atom with a nucleus of one proton and a single electron rotating about it. Next in order of increasing size of nucleus is helium. The helium nucleus consists of four protons and two electrons, so that the net charge on the nucleus is two; and rotating about this are two electrons. Next comes lithium with a nucleus containing seven protons and four electrons, leaving a net charge of three on the nucleus, and rotating about it are three electrons, and so on.

The atom is always visualized as a minute solar system with a small compact sun composed of positive and negative charges (but always with an excess of the former) and planetary electrons rotating about the sun in numbers equal to the net positive charge on the nucleus.

The nucleus of the helium atom appears to be a very stable group and we often meet with this group of four protons and two electrons which is known as an alpha particle. In the last analysis, however, this too reduces to the ultimate units of protons and electrons.

To return to the history of the radioactive substances: After the discovery of X-rays search was made of many substances to determine whether they too might not emit a penetrating radiation. Henri Becquerel performed some experiments on uranium which showed that it possessed the power of emitting a very penetrating radiation. He placed some of the salts of uranium in a black paper on top of a photographic plate and interposed between the two a piece of silver. He found on the plate a photograph of the silver. Further experiments showed that the radiation from the uranium which acted upon the photographic plate was capable of passing through thin pieces of glass and other materials. Becquerel also showed that these rays emitted by uranium possessed the power of discharging an electroscope. Later thorium was found to possess this same property.

Mme. Curie studied this behavior in a large number of substances containing uranium and thorium. She found some specimens of the mineral pitchblende which showed an activity four to five times that of uranium. Since she had already shown that this behavior was always strictly proportional to the amount of the element present, and since the activity of these substances was more than that corresponding to the amount of uranium present, some other highly active unknown substance must be present. Further work proved the correctness of this hypothesis and led to the discovery of the new element radium.

It is a very heavy metallic element. Its most remarkable properties are those centering around its disintegration. Radium is found to have the property of acting on a photographic plate and of causing the discharge of an electroscope. A detailed investigation of this behavior showed that the radium radiation is complex and is of three kinds, now called alpha, beta and gamma rays. These rays are being constantly given off by the radium at a rate entirely independent of any external conditions, such as temperature or pressure.

The alpha rays have been shown to be nothing other than atoms of helium projected from the radium atom with enormous velocities, some as high as one tenth of that of the velocity of light. The beta rays are electrons hurled from the atom with even greater speeds than the alpha particles. It is not surprising that with speeds such as these particles can penetrate considerable thicknesses of matter. Nor is it surprising that in the atomic cataclysm which leads to the

ejection of these two particles a disturbance is set up in the ether which gives rise to a very penetrating X-ray of very short wave-length known as the γ-ray.

We may consider these radiations from two points of view; their effect on the atom from which they came; and on the matter through which they pass.

Let us first consider what happens to the radium atom when it gives off radiation. What it is that causes this remarkable phenomenon we do not know, we are only able to observe what takes place and to measure the rate at which it occurs. We know that out of the 2.7×10^{21} atoms in one gram of radium 3.4×10^{10} will disintegrate per second. At this rate in 1.730 years half of the original quantity of radium would have broken up.

When an alpha particle is ejected the nucleus loses the two positive charges associated with it and so there must be a rearrangement of the electrons in the surrounding orbits. The new atom is lighter than the old one by the weight of the alpha particle which it has ejected. Its atomic number, as the number of positive charges in the nucleus is called, is smaller by two and its chemical and physical properties are no longer the same. It is a new substance. It is called radon (radium emanation) and happens to be a gas. This atom, like its parent, is unstable and after a time emits an alpha particle and forms a new substance known as radium A. Radium A eventually passes into radium B. Radium B manifests its instability in a slightly different fashion by emitting an electron or beta ray and so the process continues until eventually a product is attained which is stable and undergoes no further changes. This product is lead. It is only a matter of time before each atom of radium will become an atom of lead.

Similar processes take place in atoms of other radioactive elements. It is this characteristic of disintegration that distinguishes the atoms of the radioactive substances from the other elements. They are continually undergoing change and passing from an atom of one kind of substance to an entirely new substance. It is this behavior and its explanation by Professors Rutherford and Soddy that gave the first proof that an atom was not a simple entity but a complex one, and that by some kind of rearrangement it could be changed into another substance. What takes place in the atoms of the radioactive elements is the realization of the dreams of the alchemists, the transmutation of the elements.

There is still another way in which the radioactive elements have given us an insight into the structure of matter, due to the work of Sir Ernest Rutherford and his coworkers in the Cavendish Laboratories. The alpha particles shot off from radioactive atoms have been used as probes with which to search deep into the centers of other kinds of atoms. This method has been very fruitful and has given much information regarding the sizes and weights and atomic numbers of atomic nuclei.

It has been possible by bombarding atoms with swift flying alpha particles to partially disintegrate them. Thus we have not only been able to observe the transmutation of the elements taking place in the radioactive series, but we have even been able to cause it to take place at will in other substances, if only on a very small scale.

In the hands of the physicist and chemist radium has been a powerful tool. In the hands of the medical man it is in its infancy as an aid to the treatment of disease, particularly malignant growths such as cancer.

If we but knew how to control disintegration of this kind and cause it to take place at will, the engineer might find in a few grams of matter the energy for which he now has to consume tons of fuel and our whole economic system and daily life might be revolutionized.

SHIPS

By Professor EZRA BOWEN
LAFAYETTE COLLEGE

It is generally supposed that harbors, ready cargoes and an abundance of shipbuilding materials make a great shipping nation. But there have been nations which possessed all these qualifications in the first degree, and which at the same time had almost no shipping business. On the other hand Holland, for example, with no important source of cargoes or shipbuilding materials had at one time almost a monopoly of the world's shipping trade. The ships of Norway, the most intensely maritime of modern nations, make comparatively little use of home harbors. Nowhere in the literature of history or of economics are these things explained.

Let us see if we can not apply the method of science to the enigma—proceed exactly as would the chemist or geologist or diagnostician. First, we shall isolate and define our problem. Next we shall try to form an hypothesis that explains it. Then, by assembling the greatest possible number of similar instances, we shall test this hypothesis to see if it is worthy of future detailed study. Let us try it.

Our problem, stated in simplest terms, is: What is the key circumstance which forces or leads nations to develop a great overseas carrying trade?

An hypothesis is an intelligent guess, not a random shot, but a conjectured explanation based on experience. It should rest upon a rather wide experience, the experience of actual contact or, where that is impossible, the second-hand experience of reading and study. But an hypothesis, however intricate and extensive or simple and special and in whatever science, is nothing more or less than a thoughtful conjecture from experience.

The following hypothesis is not offered of course as a single peg upon which to hang the whole of sea history. Other explanations of the presence or absence of a carrying trade—such as an abundance, or lack of harbors, cargoes, shipbuilding materials—are entirely valid. What we now offer is merely a collateral hypothesis which may prove upon further investigation to be founded upon a universal and key circumstance: Nations do not develop an overseas carrying trade until they are forced to; mankind does not go to sea except by necessity; man is not a marine animal. A nation develops an overseas carrying trade only when other outlets for economic activity are absent or have been destroyed.

Having defined our problem and presented our rather simple hypothesis, the next step in the process is to test this hypothesis by induction: we must turn back through the pages of history and assemble a complete array of nations which have, as a matter of clear and definite record, established an important overseas carrying trade, and find if in every instance they have lacked adequate outlets for economic activity.

The first nation to develop a notable merchant marine and to secure the bulk of the world's carrying trade was the Phoenician.[1] Phoenicia, a narrow strip of territory extending along the eastern shore of the Mediterranean, was well situated for trade with the dominant civi-

[1] Day, Clive, "A History of Commerce," p. 13.

lized countries of the time.[2] Tyre and Sidon were its principal cities. Both were on barren rocky islands near the coast.[3] The Phoenicians, a highly developed people, made extensive voyages and furnished reliable means of sea transport. They learned to direct their course at night by the North Star, which was called by the Greeks the Phoenician Star. Their ships were for centuries the accepted models of naval design.[4] They were the discoverers of the western Mediterranean; it was the Phoenicians who brought the first rudiments of civilization to Spain.[5] Just before the opening of the Christian era, King Necho sent out an expedition to attempt a circumnavigation of the continent of Africa. He also started to dig a canal across the Isthmus of Suez. The canal was afterward completed—nearly two thousand years before Benjamin Disraeli, a near relative of the Phoenicians, put a backbone into the amorphous British Empire by acquiring the Suez Canal.[6]

This great seafaring people, the first seafaring people to whom the term great could possibly be applied, lived upon a coastal plain not more than two hundred miles long and about twenty miles wide.[7] Natural resources were scarce, grazing was poor and farming worse.[8] Agriculture and the trades were soon overcrowded and this energetic people, hemmed in between sea and mountains, was literally forced into the sea.[9] "They could gain a scanty food supply from the level ground, and had timber in abundance on the mountains that separated them from the interior, but had to look to trade with other peoples for the means of growth which their home denied them."[10]

Greece was the next nation in the world's history to develop an important overseas carrying trade.[11] The foreign trade of very ancient Greece was carried entirely in Phoenician ships.[12] The Greeks were a pastoral people according to Breasted, who finds Hesiod (700 B. C.), the peasant poet, "looking with a shrinking eye upon the Sea."[13] The pre-Hellenic Greeks produced an exportable surplus of oil and wine, but a rapidly growing population soon met with a deficiency in many products, especially in grain and other fundamentals.[14] It was not until population had outrun the agricultural possibilities of a fairly fertile—but extremely hilly and rocky—land that any considerable carrying trade was developed.[15] Miletus was the first of the Greek cities in commercial importance. The people of this Carian city were cut off by surrounding mountains from nearly all economic activity by shipping and fishing—a situation a great deal like that of Genoa, a city destined to attain great commercial importance some centuries later.[16] The little island of Aegina, rocky and sterile, supporting even to-day but six thousand inhabitants, became for a time the most

[2] Knight, M. M., "Economic History of Europe," 1926, pp. 28–29.

[3] Botsford, G. W., "A History of the Ancient World," p. 39.

[4] Breasted, J. H., "A History of the Early World," pp. 287–8.

[5] Hall, Edward Everitt and Susan, "Spain," p. 17.

[6] Holt and Chilton, "European History, 1862–1914," pp. 192–3.

[7] Stephenson, J., "The Principles and Practice of Commerce," p. 106.

[8] Botsford, G. W., "A History of the Ancient World," p. 39.

[9] Botsford, *loc. cit.*

[10] Day, Clive, "A History of Commerce," p. 12.

[11] The term Greece is used to indicate all the Hellenic regions.

[12] Day, *op. cit.*, p. 18.

[13] Breasted, J. H., "A History of the Early World," p. 259.

[14] Rostovtzeff, "A History of the Ancient World," p. 371.

[15] Breasted, J. H., "A History of the Early World," p. 287.

[16] *Encyclopedia Britannica*, Eleventh Ed., *Art.*, Caria.

important market of the Greek world; it amassed fabulous riches from a commerce penetrating all seas.[17] In the case of Greece, the second notable shipping nation of the world, we find—as with Phoenicia—that an energetic people soon exhausted the rather meager agricultural opportunities of its native land and was forced to go down to the sea in ships.

During the early Middle Ages shipping and navigation, along with many other arts and sciences, languished.[18] Only in the far north, in Scandinavia, do we find a truly seafaring people, during these long centuries when the world's pulse beat so feebly—when the world was slowly convalescing from its first heavy attack of civilization. These hardy northern sea-rovers sent out ships in every direction over the cold gray Atlantic—to Iceland, to Greenland and, five hundred years before Columbus, to North America.[19]

But the Norsemen were not a commercial people; they were fishermen and raiders.[20] They put out in tiny, open boats looking for new fishing grounds, where fat fish were to be had for the taking, or new raiding grounds, where fat farmers and burghers could be despoiled of their properties.[21] We know what worthy ships they used, for one was discovered a few years ago in a burial mound in southern Norway, where it had been preserved, it is supposed, since the ninth century.[22]

From the time when ancient Greece attained her greatest glory, there were centuries, therefore, during which sea traffic languished, and no nation developed an important merchant marine. Finally Byzantium, or rather Megara (Constantinople), became the world's shipping center.[23] Constantinople was handicapped economically—as Tyre and Sidon, Miletus and, later, Genoa and Pisa—by a rocky broken terrain, constricted territory and pressing border of towering hills. The Byzantians also were squeezed out upon the sea.

Then Constantinople yielded primacy to Venice, whose rich merchants sent their captains to every corner of the known world.[24] The origin of this medieval city-state can be traced to the "barbarian invasions," when people from the mainland of Europe were driven to find refuge upon islands in the lagoons of the north shore of the Adriatic. But only the scantiest living was obtainable on these meager footholds,[25] and the fugitives were "*forced*[26] to seek a living upon the sea, first as fishermen but more and more as merchants."[27]

The Venetian fleet was the finest and the Venetian navy was the most powerful in the world. In 1268 Venice presented to France ships that were 110 feet over all, carried a complement of more than one hundred men and must have measured four or five hundred tons, while English ships of the period rarely exceeded fifty or one hundred tons.[28] England, later to become mistress of the seas and to retain that position for a longer time than any nation, was in the Middle Ages very unimportant.[29] The

[17] Day, Clive, "A History of Commerce," p. 19.

[18] Thatcher and Schwill, "Europe in the Middle Ages," pp. 436–7.

[19] Du Chaillu, P. B., "The Viking Age," Vol. II, p. 518, *ff*.

[20] *Cf.* Thatcher and Schwill, *op. cit.*, chap. ix–x.

[21] *Cf.* Haskins, C. H., "The Normans in European History," chap. i and ii.

[22] Day, Clive, "A History of Commerce," p. 70.

[23] "Cambridge Medieval History," Givatkin and Whitney, Eds., Vol. III, p. 762.

[24] Bemont and Monod, "Medieval Europe," p. 349.

[25] Lodge, R., "The Close of the Middle Ages," p. 140.

[26] Italics ours.

[27] Day, *op. cit.*, p. 90. (Italics ours.)

[28] Day, Clive, "A History of Commerce," p. 72.

[29] *Cf.* Cutts, E. L., "Scenes and Characters of the Middle Ages," pp. 461–518.

"fact" that the seafaring disposition is "in the blood of Englishmen" is more than questionable: to the contrary, it appears that Englishmen, as other men, did not go to sea until circumstances left scant choice. Like Phoenicia—and later, Great Britain—Venice developed and consolidated her commercial supremacy by establishing many and far-flung colonies. Through this practice she controlled the commerce of the Mediterranean even more efficiently than Great Britain controlled the commerce of the world in the nineteenth century—though of course the field of opportunity was much narrower.[30] The entire citizenry of Venice was engaged in commerce or trade.[31]

Genoa and Pisa were the commercial rivals of Venice.[32] Both were situated on the steep, rocky west coast of Italy, where agriculture in any substantial sense was impossible. Each had a hinterland of unyielding mountainous country which cut off its inhabitants from any employment except the working of gardens hewn out of rocky hillsides—though with a small river valley to the south and east, the Pisan background was the less difficult. These people were "forced," no less than the citizens of Venice, to seek a living upon the sea.

Spain was the next nation to strut her hour upon the commercial stage and to develop an important overseas carrying trade.[33] Now Spain differed from these other nations, Phoenicia, Greece, Byzantium, Venice, Genoa and Pisa, with their constricted territory, their precarious foothold upon a narrow shore: Spain was a great broad land, but it is easy to overdraw the agricultural opportunities of Spain. She has, throughout most of her history, been more of a grazing than an agricultural land,[34] and it is well known among economists that a grazing economy supports far fewer persons per square mile than almost any other.[35] Over the entire area, the annual rainfall of Spain is less than twenty inches.[36] A great part of the land is rugged, mountainous, unyielding.[37] Toward the end of the Middle Ages, soil exhaustion and the invasions of the Moors—a series of long, bitter wars—had almost totally wrecked Spain's economy. Manufacture and resources fell almost wholly into the hands of Moors and Hebrews.[38] It was then that Spain began to look seaward and to develop, later, a notable merchant marine —when opportunities for other forms of economic activity were either wrecked, exhausted or preempted. Spain, like Phoenicia, Greece and Venice before her, and England and Holland afterward, developed and consolidated her overseas carrying trade by the acquisition of colonies; but Spain never reached the peak of commercial dominance attained by those nations.

Portugal, during the fifteenth and sixteenth centuries, became a power in overseas trade.[39] Her commerce was not only large in proportion to her area and population, but equaled the trade of the greatest nations in the world.[40] At the close of the Middle Ages, Portugal had a population of scarcely more than a million—perhaps even less.[41] Her car-

30 Thatcher and McNeal, "Europe in the Middle Ages," pp. 294–5, 432.

31 Grant, A. J., "A History of Europe," p. 381.

32 "Cambridge Medieval History," Vol. III, p. 762, Vol. V, pp. 226–7.

33 Burke, "A History of Spain," p. 325.

34 *Cf.* Hume, M. A. S., "The Spanish People," chap. viii.

35 Ratzel, F., "History of Mankind," (translated from 2d German Ed.), Vol. 1, p. 10.

36 Smith, J. Russell, "Industrial and Commercial Geography," p. 422.

37 Chisholm, G. G., "Handbook of Commercial Geography," p. 444.

38 *Cf.* Hume, *loc. cit.*, also Day, "A History of Commerce," pp. 174–5.

39 Smith, Preserved, "The Age of the Reformation," p. 524.

40 Stephens, H. M., "Portugal," p. 156.

41 Smith, *op. cit.*, p. 458.

rying trade soon began to rival Spain's and to surpass, by far, the commerce of any northern European state.[42] In the middle of the fifteenth century Portuguese caravels were recognized as the best sailing ships in the world.[43] Here again we have a mountainous, meager soil, unsuited for any form of production but grazing, wine-raising and arboriculture.[44] The ports of Lisbon and Orporto, backed as they were by rocky hills extending up and away to the bleak and desolate Serra da Estrella, were located almost exactly as the great Italian ports of the preceding century, Genoa and Pisa—and the Phoenician ports of Tyre and Sidon. The inhabitants of Portugal were forced from their narrow footing on the coast of the Iberian Peninsula by rocky hills and steep mountain slopes; they were compelled to become a seafaring people by circumstances much like those which surrounded the Phoenicians, Genoese and Pisans. After Portugal, the Netherlands assumed primacy in the world's carrying trade.[45]

There are no mountains in Holland, quite true; but the thrifty, energetic Dutch people were hemmed in, none the less: powerful neighbors confined Holland to a small swampy area, fit only for precarious grazing and a rather limited agriculture. The soil was rich, but it had to be drained at great pains and expense; the well-known thoroughness with which this was done is complete evidence of the scarcity of agricultural opportunities.[46] During the war for independence there was a notable increase in population.[47] Clive Day says: "The Dutch were forced to the sea by the difficulties of life at home. . . . Before 1602, sixty-five ships had made the return voyage to India and throughout the 17th century an active commerce was maintained both with Asia and America."[48]

Holland developed a merchant marine greater than the fleets of any nation before her, and came nearer to obtaining a monopoly of the world's commerce than any nation since the day when "the world" meant the shores of the Mediterranean.[49] We learn that the Dutch owned four fifths of all ships engaged in ocean commerce and that ten Dutch ships traded to the Barbadoes for one English.[50] In proportion to number of inhabitants and extent of natural resources, the Dutch developed the most magnificent commerce of any nation after the Phoenicians and the Venetians. More ships were built in Holland than in all the yards of Europe.[51] Here again —as with Venice—we have a people living upon constricted swampy land, meagerly endowed with natural resources, cut off from large economic opportunities.[52] They went to sea—not because of fine harbors or abundant shipbuilding materials or because "it was in their blood"—the Dutch set out upon the broad ocean because circumstances forced a seafaring life upon them.

The seventeenth century saw the rise of another poor, small nation to a position of commercial power. In 1600 England had scarcely four million inhabitants.[53] Throughout the sixteenth century she was counted a poor nation.[54]

[42] Day, Clive, "A History of Commerce," p. 184.

[43] Egerton, H. E., "The Origin and Growth of Greater Britain," p. 27.

[44] Chisholm, G. G., "Handbook of Commercial Geography," pp. 446–7.

[45] Smith, *op. cit.*, p. 442.

[46] Lyde, L. W., "The Continent of Europe," pp. 263–4, 267.

[47] Webster, W. C., "A General History of Commerce," p. 146.

[48] Day, Clive, "A History of Commerce," pp. 190–1.

[49] Egerton, H. E., "The Origin and Growth of Greater Britain," pp. 49–50.

[50] Day, *op. cit.*, p. 223.

[51] Webster, W. C., "A General History of Commerce," p. 148.

[52] Chisholm, G. G., "Handbook of Commercial Geography," p. 373.

[53] Smith, Preserved, "The Age of the Reformation," p. 453.

[54] Green, J. R., "Short History of the English People," pp. 326–7.

Climate favored grazing rather than tillage; mineral resources were still largely unknown and therefore of little value. As late as the reign of Elizabeth, England imported almost all "artificiality," as finished manufactures were called.[55] At the beginning of the eighteenth century, wool was still her largest export.[56] It was from these meager circumstances that England developed a supremacy in the carrying trade that lasted the better part of four centuries and which remains undisputed. But it is very important to remember—and almost nowhere is it fully appreciated—that during the Middle Ages the English were not great navigators in spite of the facilities offered by excellent harbors and rivers penetrating far inland.[57] English ships were miserable little traps, far outclassed by those of Norway, Venice, Pisa and Genoa.[58] English commerce was largely in the hands of foreigners.[59] It was not until the population of England began to outgrow agricultural opportunities that her people turned their eyes seaward. In the bitter competition for commercial supremacy which ensued between the British and the Dutch, Great Britain triumphed. The shock and burden of conflict with the declining power of France and the rising power of England shattered Holland's commercial supremacy.[60] But the Dutch merchant marine is still notable; on a per capita basis it is surpassed to-day by few.[61]

Which nations, in modern times, have the largest per capita ship tonnage—which nations, in proportion to size, have developed the most important merchant fleets? They are, in the order named, Norway, Great Britain, Holland, Denmark, Sweden.

PER CAPITA TONNAGE IN MERCHANT FLEETS OF LEADING NATIONS

	Per capita tonnage	Population[62]	Tonnage[62]
(1) Norway	.964	2,650,000	2,555,000
(2) Great Britain	.448	42,920,000	19,274,000
(3) Holland	.353	7,315,000	2,585,000
(4) Denmark	.295	3,419,000	1,008,000
(5) Sweden	.201	6,036,000	1,215,000
(6) United States[63]	.099	117,823,000	11,605,000
(7) France	.083	39,400,000	3,262,000
(8) Italy	.075	38,755,000	2,894,000
(9) Japan	.061	61,082,000	3,741,000
(10) Germany	.048	62,539,000	2,893,000

Norway is a rugged, bleak land; gorgeously beautiful for a few fine days in summer, in winter it is dreary.[64] Lumbering, hunting, trapping and, in a limited sense, dairying and agriculture are the only possible occupations.[65] Towering snow-topped mountains rise directly from the sea, forming the jagged fjords which make such excellent harbors. The whole country is mountainous and rocky; 75 per cent. of its area is unproductive and 22 per cent. is in forest[66]—in brief, a land which seems especially designed to make a life upon the sea appear attractive. Here in Norway we find the seafaring life developed to its highest pitch—possibly the highest pitch reached in the whole history of man's effort to make a living. England is a great seafaring nation, but the per

55 Smith, *op. cit.*, p. 535.

56 Webster, W. C., "A General History of Commerce," p. 172.

57 Williamson, J. A., "Maritime Enterprise," chap. xiii.

58 *Cf.* Cutts E. L., "Scenes and Charts of the Middle Age," pp. 416–474.

59 Williamson, *op. cit.*, pp. 16, 19.

60 Webster, W. C., "A General History of Commerce," p. 164.

61 See table, *infra.*

62 "The Statesman's Year-Book," 1926.

63 Included in this reckoning are about six million tons of coastwise shipping. If this were excluded the United States should rank tenth.

64 Lyde, L. W., "The Continent of Europe," p. 111.

65 Huntington and Williams, "Business Geography," p. 250.

66 Smith, J. Russell, "Industrial and Commercial Geography," p. 441.

capita tonnage of little Norway is more than twice as great.

The industrial revolution meant more to Great Britain than to any other land.[67] But the opportunities for earning a living, which were opened up by the development of industrialism, were soon exhausted by a rapidly growing population, and throughout the nineteenth century, the heyday of industrialism, a nearly constant emigration from the British Isles indicated a sufficient scarcity of domestic, economic opportunities to insure the attractiveness of a seafaring career.[68] The first full burst of industrialism could not offer sufficient attraction during the early part of the nineteenth century to counterbalance an interest in shipping that had been gaining momentum for two hundred years and by the end of the century a teeming and vigorous population produced a demand for jobs which far outran the home supply.[69]

Modern Holland has about the same economic opportunities—or lack of them—as medieval Holland (Netherlands), save that territory is even more narrowly constricted. The result, as we see from the table, is that modern Holland also has developed a notable merchant marine. Mineral resources are almost wholly wanting; bad natural drainage makes agriculture difficult.[70] The climate is not pleasant.[71] Her struggles with France and England took from Holland leadership in the world's carrying trade, but did not remove the key incentive to the development of an important overseas commerce, the lack of domestic, economic opportunities. Her carrying trade returned.

Denmark's agricultural possibilities exceed Norway's and are but little inferior to England's or Holland's, but compared with the more favored nations of the earth, Denmark yields meager returns to economic endeavor. Natural resources—other than a capable and courageous population, which is probably the handsomest resource a nation may possess—are entirely lacking.[72] Farming is carried out upon what is practically a synthetic soil.[73]

Sweden has less than a quarter the per capita merchant tonnage of Norway; but she owns more than twice as much as her nearest rival; we need go no further. The ratio of Norway's per capita tonnage to Sweden's is four to one in favor of Norway: opportunities for economic activity at home are probably well represented by the reverse ratio of four to one in favor of Sweden.[74] In Sweden there is iron and there are other mineral resources, but not in profusion, and there is no coal.[75] Sweden has fertile valleys, but the land is hilly and rocky[76]—less productive, on the average, than land in Denmark or Great Britain. The climate of Sweden is not pleasant; rain or snow falls during a large part of the long winter. Her days are not shrouded in darkness and rain during four months of the year as with northern and western Norway; still Swedish winters are far from attractive.[77]

In testing our hypothesis, by the inductive method, we have assembled all instances of notable seafaring nations

[67] Dietz, F. C., "The Industrial Revolution," pp. 23–4.

[68] Egerton, H. E., "The Origin and Growth of Greater Britain," pp. 8–9.

[69] Demangeon, A., "The British Empire," pp. 63–4; Egerton, *op. cit.*, says (p. 215) that from 1910–14 emigrants to Canada alone numbered 614,088.

[70] Chisholm, G. G., "Handbook of Commercial Geography," pp. 373–4.

[71] Lyde, L. W., "The Continent of Europe," p. 287.

[72] Smith, J. Russell, "Industrial and Commercial Geography," pp. 156–7.

[73] Smith, *loc. cit.*

[74] Chisholm, G. G., "Handbook of Commercial Geography," p. 436.

[75] Huntington and Cushing, "Principles of Human Geography," pp. 8–179.

[76] Chisholm, *loc. cit.*

[77] Smith, J. Russell, *op. cit.*, p. 144.

that appear in history. Beginning with the Phoenicians of 1500 B. C., every great tribe of sea-rovers has come under our view: the Phoenicians, the ancient Greeks, the Byzantians, the ancient Scandinavians, the Venetians, the Genoese, the Pisans, the Portuguese, the medieval Dutch, the seventeenth, eighteenth and nineteenth century English, the modern Norwegian, British, Dutch, Danish and Swedish peoples. In every case we found a people living of course upon a seacoast having at least one usable harbor; but many peoples that could not possibly be included in our array of important carrying nations were so situated. The common factor, the key factor, in every case appeared to be a lack of sufficient outlets for economic activity; in most cases we found economic opportunities upon a starvation basis. We found, in brief, that *a nation develops an overseas carrying trade only when other outlets for economic activity are absent or have been destroyed.* But this is not to deny of course that harbors, cargoes, shipbuilding materials and an energetic population are fundamental factors in the development of a merchant marine: here is merely a collateral hypothesis which suggests that these are not enough, and that to ensure a nation's developing a notable carrying trade there must be an unattractive domestic ecography.

This brief essay does not pretend of course to be a piece of historical research —all facts presented are common knowledge: it pretends to be no more than an exercise in the interpretation of history, leading to a perhaps not wholly valueless hypothesis of the rise and fall of merchant fleets, in no instance have we gone behind our authorities, and it is possible that every case cited offers an opening for further research, which might either strengthen or utterly destroy our hypothesis. Certainly the case of China, a land rich in resources—with splendid harbors, cargoes, a wealth of shipbuilding materials, and with navigable rivers extending far inland, and which nevertheless has owned very little shipping—could bear further research. Then there are the North Coast Africans; in this case there is no possibility of the seafaring-blood hypothesis' coming to bear. The region was repeopled at various times by the most widely differing human strains: Phoenicians, Moors and even Vandals. In every case a notable sea trade flourished. How did Vandals from the dense woods of Central Europe or the dry Hungarian plain develop in a generation the "seafaring instinct"? Here is another opportunity for research. Should this little essay initiate inquiry into these and other instances and into the general hypothesis submitted it will have reached its furthest aim.

FOOD PREJUDICES

By Dr. CHARLES W. TOWNSEND
IPSWICH, MASSACHUSETTS

THE educated cosmopolite does not hesitate to try strange foods. Not so the savage, the child and the ignorant. In these three classes, food prejudices—often curious and irrational—abound. In California, a man and woman sitting near me in the car expressed great curiosity about the immense fields of blue-green French artichokes. I explained what these vegetables were, how they were served and eaten, dwelt on their toothsomeness and recommended a trial. "Oh, no!" said the man with the utmost finality, "We never eat strange foods."

Here spoke the cosmopolite's "contemporary ancestor." In a hostile world the savage must take heed what he eats or he may rue the day. Although many of his food taboos are doubtless fanciful, others are based on substantial reasons. One of his remote ancestors may have experimented with a strange food and was poisoned by it, and the tradition has become fixed in the tribe. An overripe oyster may cause death, while venison, aged in the cache, may be a nourishing delicacy. His tribes for generations have known what foods are good and he avoids all others—all "strange foods." Food prejudices to-day, therefore, are due to inheritance from our savage ancestry; they are atavistic.

On both the American and European shores of the Atlantic Ocean two shellfish are common, the soft-shelled clam, *Mya arenaria,* and the edible mussel, *Mytilus edulis.* The species of these two mollusks are the same on both sides of the water. In Europe, mussels are eaten freely but not clams, while the reverse is the case on the American side. This prejudice, against the mussel here and against the clam there, extends back to prehistoric times, for while clam shells abound here in kitchen middens or ancient shell heaps and mussel shells are merely accidental, in Europe the exact opposite is the case.

Professor Edward S. Morse, in his study of the changes in the shell of the clam,[1] was amazed to find no clam shells in the Baltic shell heaps, while the living mollusks abounded in the nearby estuaries. The prehistoric people like their modern successors did not eat the clam. He adds: "It was the same in England; the clam had never been eaten, even in ancient times. It is a common shell there, and thousands of barrels are shipped to the Newfoundland fisheries for bait. We learned the epicurean delights of the clam from the North American Indians." In a recent visit on the Norfolk coast of England I had great difficulty in persuading a company of educated English people to taste the clam!

Children are nearer the savage state, more atavistic than their educated parents, and strange foods are often to them abominations. The wise parent instils the precept, "Eat what is set before you and be thankful," and, to take the sting off, he may add, with a twinkle in his eye, "put your food into your mouth and not into your lap." The unwise parent allows the innate talent for food prejudices to grow strong in his young hopefuls, and even boasts that his little Johnny or Mary can not eat this and can

[1] SCIENTIFIC MONTHLY, xxi, 1925, p. 424.

not eat that. I do not refer here to certain rare idiosyncrasies, as, for example, when even a minute amount of egg causes symptoms of poisoning, for that fortunately does not often happen to Johnny and Mary, and they have no inborn prejudices which warn them against such food. Food prejudices run rife among them. It may be observed, as in the case of the travelers and the French artichoke, that the victim does not even taste the food that falls under his taboo. His mind is made up without that. He *knows* the food is not fit for him to eat, and the fact that others eat it and enjoy it and thrive makes no difference.

The third class mentioned above, the ignorant, is well represented—or rather used to be—by the peasant servant girl who was content with corned beef and cabbage, and refused even to taste venison and wild duck.

All of us are very near the savage state, for our civilized ancestry is but a minute fraction of our whole human ancestry. Food prejudices, therefore, abound even among the educated. In the matter of fish, this is strikingly the case. In England and in this country the various kinds of flatfish, whether known as sole, plaice or flounder, are considered good and delicate eating and bring a high price either in the market or restaurant. This is not the case in the Gaspé Peninsula, in Newfoundland and in Labrador. In Newfoundland I once read an editorial in a St. John's paper urging the use of this fish as a food and recounting the fact—singular to Newfoundlanders—that the flounder brought high prices in the States. At Grand Grève in Gaspesia I told a fisherman and his wife, at whose house I was staying, the high esteem and high price in which the flounder was held in Boston, and suggested that the next he caught should not be wasted. I am afraid I damaged my reputation for truthfulness by mentioning the price. A few days later I saw several flounders deposited as fertilizer in the garden, and, on my exclaiming at the sacrilege, he said, "Oh, they are not fit to eat!" There was nothing more to be said.

In my youth, when on codfishing excursions I caught pollack, no matter how large and fine, I was told to return them to the water as they were "not fit to eat." Nowadays this prejudice seems to have disappeared. At Grand Manan, New Brunswick, haddock and hake were formerly thrown away, and nearly everywhere along our coasts the dogfish, hated by fishermen for the damage it does to fish and nets and bait, is destroyed and cast out. It is true that it has an unpleasant name for a food fish—for there is much in a name, Shakespeare to the contrary notwithstanding—and it is also true that the dogfish is a shark, but let me add that it has firm white flesh which is nearly as good eating as that of the esteemed swordfish. The first time that I determined to try the gastronomic qualities of this fish and had expected to be obliged to prepare and cook it myself, I was agreeably surprised to find that our cook, a native of the Hebrides, welcomed it as an old friend and prepared a savory dish of it. For some reason the inhabitants of the Hebrides, or at least of that part from which she came, had no prejudices against the dogfish. To avoid this prejudice, the names "gray fish" and "rock salmon" are used here and in England.

It may be thought that the knowledge of the food on which the fish or other creatures live has a great deal to do with food prejudices, but when we consider the food of the domestic hen and of the domestic pig, it is hard to conceive of anything worse. Make no inquiry as to the food of the lobster!

Norman Heathcote, in "Birds of St. Kilda," says that the favorite dish at this island was "skate which was begin-

ning to go bad." Parenthetically, I might remark that we prefer our game "when it is beginning to go bad," and I might add that the skate like the dogfish is a kind of shark.

In Labrador, young gulls are considered great delicacies as food, while the mere idea of eating cormorants is a thing abhorrent, yet gulls feed on the flotsam and jetsam of the sea, on long-dead fish as well as on fresh ones. Cormorants, on the other hand, feed exclusively on freshly caught fish. On a cruise along the Labrador coast I once broiled the breast of one of these birds. The two sailors turned away from it in horror—I had not been able to persuade one of them, the cook, to prepare it—but the captain, a broad-minded man and one who could rise above prejudices, much to his surprise, found it delicious, as, indeed, it was. It is possible that the uncanny neck of this bird with the bare patch of orange-colored skin at the throat has something to do with the prejudice, but no one objects to the turkey which has a still more uncanny head and neck.

To "eat crow" has an unpleasant metaphorical flavor. Equally unpleasant, even abhorrent to most people, is the idea of eating crow in the literal sense. The crow stands at the head of the bird world in brain capacity. He has no food prejudices, but his bill of fare is dainty compared with that of the barnyard fowl. Now I can assert that a properly broiled or roasted crow, especially if young, compares well with pigeon or squab. Very few, I am convinced, would approach the subject with an unprejudiced mind or palate, so that, no doubt, the experiment would fail, to my discomfiture, but I can add that I have found some to agree with me. Fair judgment in such matters is difficult or impossible to the victim of food prejudices. It is conceivable that honey might taste to him like vinegar. Rook shooting and rook eating in Pickwick's time, at least, was common sport in England. A rook is a crow.

I remember reading a sportsman's recipe for cooking porcupine which included long stewings and changes of water. The recipe concluded with the advice—which was excellent under the circumstances—to throw it all away without serving. A nicely broiled porcupine steak or hind quarter, I can, however, aver from experience, to be excellent. The same can be said of woodchuck, muskrat and skunk; I have tried them all. Indians are particularly fond of skunk, which, be it added, is known in the Algonquin tongue as *shikago*—tell it not in Gath!

Explorers in savage regions often learn to divest themselves of food prejudices. Captain G. F. Lyon, of H. M. S. *Hecla,* in a voyage of discovery in the Arctic regions under Captain Parry, was a good example. He says, "All were horrified at the idea of eating foxes, but very many got the better of their delicacy and found them good eating. Not being myself very nice, I soon made the experiment, and found the flesh much resembling that of kid, and afterwards frequently had a supper of it."

Captain George Cartwright, who lived from 1770 to 1786 on the Labrador coast, was another such adventurous soul. He found his men rebelled at being made to eat venison in winter in order to conserve the salt pork which they preferred, and only by an artifice did he get them to eat polar bear.

Stefansson, in "The Friendly Arctic," gives a very good account of food prejudices among Esquimau dogs. He found that the dogs brought up far from the sea and fed on caribou and rabbit would not eat seal meat, while those brought up on the seashore and used to seal meat would not touch other game when they were taken inland. He found that in young dogs the prejudice was more

quickly overcome than in old dogs who would sometimes endure starvation rather than try the new food, and that old females were the most obstinate in refusing to give up their prejudices. This leads him to conclude—rather ungallantly, perhaps—that "this seems to extend the commonly believed-in principle of the greater conservatism of human females down into the lower animals." The highly civilized dog, used to all kinds of foods, has, as is obvious, few or no food prejudices.[2]

It is well known that the introduction of potatoes and tomatoes in Europe was a slow and difficult process, and that Indian corn meal is even now considered fit only for poultry in most parts of the British Isles, while the introduction of grapefruit as a part of the breakfast ritual has met with considerable opposition. In Labrador, turnip greens are eaten, but beet greens are thrown away.

Food prejudices are not limited to the savage, the child and the ignorant. They are found even among the intelligent and educated. An extreme case I discovered recently in an intelligent and educated man over threescore years of age. He admitted that he was much spoiled as a child and that until he was twenty-one he had refused to taste any vegetable but the potato. After this he gradually overcame many of his vegetable prejudices, but he still refuses to eat or even taste beets. The reason he can not give unless it be its color, but he admits that this is unreasonable, for he is very fond of strawberries. Of banana, watermelon and cantaloupe he has never even tasted, and he shudders to think of trying them. Although he lives in the pie belt and is fond of apple pie, he can not bring himself to try squash or pumpkin pie. How many good things in life this man has missed owing to his treasured food prejudices! How much better for him had he been brought up to eat the food set before him and be thankful, even if he did put some of the food into his lap!

[2] See also Stefansson's article on "Food Prejudices" in the SCIENTIFIC MONTHLY, xi, 1920, p. 540.

AGRICULTURAL MAGIC

By GRACE M. ZIEGLER

TRENTON, N. J.

THE history of the establishment of a scientific agriculture has been similar to that of medicine and other sciences: a series of experiments and discoveries, with beliefs based upon apparent results. Before any mechanical aids to experimentation were known, and when there were no records of facts to guide experimental activities, efforts to improve conditions were extraordinarily crude and intermingled with magical rites and ceremonies. Modern writers have sought to show an interrelationship between magic and science, and some have gone so far as to state that modern science is an outgrowth from primitive magic.

Using the term "magic" in the sense that marvelous results were believed to be produced by impossible methods, we find that in early times it formed a part of the daily life and routine of every household. With the beginning of the Roman empire, however, there began to appear evidences, not so much of a disbelief in magic as of an apologetic attitude toward it. Pliny, while making a bold pretense of disbelief, nevertheless includes in his "Natural History" scores of magical recipes, some of which he declares to be true from his own observations. Similarly, a belief in supernatural powers was maintained by some of the most learned men from the beginning of the Christian era to the end of the Middle Ages, when Joan of Arc was burned as a witch in France in the fifteenth century, and on down to the seventeenth century, when the Salem witchcraft delusion in our own country was countenanced and concurred in by political and intellectual leaders as well as by the general public.

Thus in the second century it is interesting to find Plutarch giving magical formulas in Egypt; Isidore, of Seville, in the seventh century in *Etymologies* believing that marvels could be effected through magic by the aid of demons; Alexander Neckam, in *De Naturis Rerum,* in the twelfth century attributing marvelous powers to herbs, fountains, stones and even words; Roger Bacon, in the thirteenth century, advocating the pursuit of alchemy as a means of disproving and blotting out all magical nonsense and possessing a strong belief in astrology.

Albertus Magnus believed in the wondrous virtues of stones to cure ulcers, counteract potions, conciliate human hearts and win battles. To him was attributed a remarkable story which is significant of the credulity of the thirteenth century.

William, earl of Holland, and king of the Romans, was expected at a certain time to pass through Cologne. Albertus had set his heart upon obtaining from this prince the cession of a certain tract of land upon which to erect a convent. The better to succeed in his application, he conceived the following scheme. He invited the prince on his journey to partake of a magnificent entertainment. To the surprise of everybody, when the prince arrived, he found the preparations for the banquet spread in the open air. It was in the depth of winter, when the earth was bound up in frost, and the whole face of things was covered with snow. The attendants of the court were mortified, and began to express their discontent in loud murmurs. No sooner, however, was the king, with Albertus, and his courtiers seated at table, than the snow instantly disappeared, the temperature of summer showed itself, and the sun burst forth with a dazzling splendour. The ground became covered with the richest verdure; the trees were clothed at once with foliage, flowers, and fruits: and a vintage of the richest grapes, accompanied with a ravishing odour, invited

the spectators to partake. A thousand birds sang on every branch. A train of pages showed themselves, fresh and graceful in person and attire, and were ready diligently to supply the wants of all, while every one was struck with astonishment as to who they were and from whence they came. The guests were obliged to throw off their upper garments the better to cool themselves. The whole assembly was delighted with their entertainment, and Albertus easily gained his suit of the king. Presently after, the banquet disappeared; all was wintry and solitary as before.[1]

These writers are mentioned merely as representative, and one could continue with a long list of well-known names, whose works are typical of the learning of their times and yet abound with curious beliefs. Astrology was taught in the medieval universities as the climax of mathematics and an essential part of medicine. In 1664, Sir Matthew Hale, presiding at a trial which resulted in the execution of two old women, said that there was no doubt that there was such a thing as witchcraft, which opinion was supported by Sir Thomas Browne, author of *Religio Medici* and other works, who was also present.

With even the most erudite maintaining the strange beliefs that gold might be coined from copper, the future foretold by the stars, problems of philosophy solved and nature controlled by invoking demons, it is not surprising that the principal industry of the land, agriculture, should have employed mystical rites and ceremonies to secure good crops, to combat the enemies of crops, to produce rain or to stop it, to avert hail and in general to regulate production through magic. It is difficult, however, to see any relationship between such practices and agricultural science as it is employed to-day, unless it may be that those men who were farthest advanced in their knowledge of the supposed bonds of sympathy between different things or of the effects of lucky objects and methods or of the meanings of portents tried to support their claims by finding a true basis for improvement. This theory is supported by Pliny, of whom Lynn Thorndike[2] says, "Magi stand out in Pliny's pages not as mere sorcerers or enchanters, but as those who have gone farthest and in most detail—too curiously, in his opinion—into the study of nature." Thorndike himself found that "magicians were perhaps the first to experiment," and Sir James Frazer[3] calls magicians "the only professional class" among the lowest savages, stating that "they were the direct predecessors, not merely of our physicians and surgeons, but of our investigators and discoverers in every branch of natural science. They began work which has since been carried to such glorious and beneficent issues by their successors in after ages; and if the beginning was poor and feeble, this is to be imputed to the inevitable difficulties which beset the path of knowledge rather than to the natural incapacity or wilful fraud of the men themselves." However that may be, the use of magic in early agriculture forms an entertaining study.

Among the earliest beliefs is that of the corn spirit, or the embodiment of a mystical spirit or life in the new corn and the new fruits. Coincident with this belief was the observance of the sacrament of the first fruits, or the eating of the corn spirit, which is sometimes represented in human form and sometimes in animal form. Many instances have been found of the sacramental eating of animals at harvest time, while occasional examples among the savages have been discovered of the killing of human representatives in a spirit of sacrifice. The corn spirit, however, was usually considered to reside in the last sheaf of the grain and to eat a loaf

[1] Godwin, William H., "Lives of the Necromancers" (New York, 1835).

[2] Thorndike, Lynn, "Magic and Experimental Science" (New York, 1923).

[3] Frazer, Sir James, "The Golden Bough," abr. (New York, 1923).

made of the last sheaf was to eat the spirit itself. For example, in Scotland and in Sweden, the last sheaf was made into a loaf in the shape of a woman and little girl, respectively, and eaten sacramentally by the family. Similarly, in La Palisse, France, a man made of dough was hung upon a fir-tree carried on the last harvest wagon, and both taken to the mayor's house. After the harvest was over the dough-man was broken in pieces by the mayor and given to the people to eat. The solemnity accompanying such rituals is evidence of the desire to propitiate the corn spirit so that a plentiful harvest might be had the following year.

While the sacramental eating of the first fruits continued in certain localities for centuries, a later belief developed in which the fruits of the earth were conceived as created rather than as animated by a divinity. In line with this belief, a portion of the products were offered to the gods producing them, probably at first to provide sustenance for the gods, but later the offerings were made in a spirit of homage, or tribute. Many of the ancient deities of vegetation were worshiped by such conciliatory sacrifices: the Athenians and other Greek peoples offering the first wheat and barley harvests to Demeter and Persephone at Eleusis; the Romans sacrificing the first ears of corn to Ceres and the first of the new wine to Liber, with none of the people daring to eat of the new corn or drink the new wine until these sacrifices had been offered by the priests.

Isis and Osiris were worshiped in Egypt in connection with the production of food. Egyptian agriculture depended upon the annual inundation of the Nile, and at the rising of the river there was celebrated the festival of Isis, who was mourning for Osiris, for if there was too much water, or too little, a famine would result. Frazer described an illustration in the temple of Isis at Philae which explained the connection Osiris was supposed to have with the harvest.

Here we see the dead body of Osiris with stalks of corn springing from it, while a priest waters the stalks from a pitcher which he holds in his hand. The accompanying inscription sets forth that "This is the form of him whom one may not name, Osiris of the mysteries, who springs from the returning waters." Taken together the picture and the words seem to leave no doubt that Osiris was here conceived and represented as a personification of the corn which springs from the fields after they have been fertilized by the inundation. This, according to the inscription, was the kernel of the mysteries, the innermost secret revealed to the initiated. So in the rites of Demeter at Eleusis a reaped ear of corn was exhibited to the worshippers as the central mystery of their religion. We can now fully understand why at the great festival of sowing in the month of Khoiak the priests used to bury effigies of Osiris made of earth and corn. When these effigies were taken up again at the end of a year or of a shorter interval, the corn would be found to have sprouted from the body of Osiris, and this sprouting of the grain would be hailed as an omen, or rather as the cause, of the growth of the crops.

Rejoicing at harvest-time was not permitted the Egyptian, for in cutting the grain he was severing the body of the corn-god and in threshing it was trampled to pieces. Accordingly, when the first sheaf was cut, it was the farmers' custom to beat their breasts and lament, calling upon Isis in the form of a melancholy chant. Similar lamentations for the corn-god killed by the sickles of the reapers were offered in Phoenicia and other parts of Western Asia.

The magical rites and ceremonies performed at planting and harvest time to ensure good crops ranged from simple treatments of seed or fields to elaborate ceremonials lasting several days and participated in by entire communities. Likewise, the enemies of crops had each its own magical remedy—too much or too little rainfall, hail, vermin, diseases and other causes of infertility.

With Pliny, making a show of disbelief in magic, the more elaborate rituals are not referred to by him, but scores of the

simpler miraculous remedies are scattered through his work. He says, for instance:

As for other seed-corne it will escape the danger of the worme, if it . . . be sowed in and about the change of the Moone, namely, when she is not to be seene above the earth in our hemisphere. Many there be who practise other remedies: and namely for Millet, they would have a toad to be carried round about the field before that it be harrowed; which done, to bee put close within an earthen pot, and so buried in the middest of the said field: and by this meanes forsooth, neither Sparrows will lie upon the corne, nor any worme hurt it. Marie, in any case this same toad must be digged out of the ground againe before the field bee mowed, else will the Millet proove bitter in tast. The like experiment they say is of a Moldwarpes shoulder, for if any corne be sowed or touched therewith before, it will come up the better and bring more encrease. . . . But what remedie against the blast and mildew, the greatest plague that can befall upon corne? Mary pricke downe certain Lawrell boughs here and there among the standing corne, all the said mists and mildews will leave the corne and passe to the Bay leaves, and there settle.[4]

Of the weather conditions as affecting crops Pliny for the most part warily quotes previous writers:

Varro affirmeth, That if about the retrait of Harpe-star Fidicula, which is the beginning of Autumne, a man paint a cluster of grapes, and consecrate it to the gods among the Vines, the stormes and tempests of wind and raine will do lesse harme to the fruit hanging thereupon. *Archibius* in a booke that hee wrote to King Antiochus, saith, That if a landtoad be put into a new earthen pot that never was occupied before & the same enterred and covered within the ground in the middest of a corne field, the corne shall take no harme that yeare by any tempests whatsoever. . . . In Persia they are persuaded, That a perfume of such Agathes, turneth away tempests and all extraordinarie impressions of the aire, as also staieth the violent streame and rage of rivers. But to know which is proper for this purpose, they use to cast them into a cauldron of seething water: for if they coole the same, it is an argument that they be right. But to be sure that they may doe good, they must be worne tied by the haires of a Lions mane. . . . If it happen to thunder about the feast Vulcanalia, Figges will fall from the tree. The remedie thereof is to strew the plots before with Barley straw.

With the right amount of rainfall having such an important effect upon agriculture, it is not surprising that methods of producing rain, or of stopping it, were sought after and some curious devices practiced. Thus, for example, "in a village near Dorpat, in Russia, when rain was much wanted," Frazer tells us, "three men used to climb up the fir-trees of an old sacred grove. One of them drummed with a hammer on a kettle or small cask to imitate thunder; the second knocked two fire-brands together and made the sparks fly, to imitate lightning; and the third, who was called 'the rain-maker,' had a bunch of twigs with which he sprinkled water from a vessel on all sides." He also tells of other interesting beliefs regarding the production of rain:

It is said that the Aymara Indians often make little images of frogs and other aquatic animals and place them on the tops of the hills as a means of bringing down rain. The Thompson Indians of British Columbia and some people in Europe think that to kill a frog will cause rain to fall. In order to procure rain people of low caste in the Central Provinces of India will tie a frog to a rod covered with green leaves and branches of the *nim* tree (*Azadirachta Indica*) and carry it from door to door singing:

"Send soon, O frog, the jewel of water!
And ripen the wheat and millet in the field."

A few examples of practices of the North American Indians from the same author are interesting.

Amongst the Omaha Indians of North America, when the corn is withering for want of rain, the members of the sacred Buffalo Society fill a large vessel with water and dance four times round it. One of them drinks some of the water and spirts it into the air, making a fine spray in imitation of a mist or drizzling rain. Then he upsets the vessel, spilling the water on the ground; whereupon the dancers fall down and drink up the water, getting mud all over their faces. Lastly, they squirt the water into the air, making a fine mist. This saves the corn. In spring-time the Natchez of North America used to club together to pur-

[4] Pliny, "Historia Naturalis" (Holland trans., London, 1601).

chase favourable weather for their crops from the wizards. If rain was needed, the wizards fasted and danced with pipes full of water in their mouths. The pipes were perforated like the nozzle of a watering-can, and through the holes the rain-maker blew the water towards that part of the sky where the clouds hung heaviest. But if fine weather was wanted, he mounted the roof of his hut, and with extended arms, blowing with all his might, he beckoned to the clouds to pass by.

In Morocco, ball-games of the hockey type are played for rain-making purposes, the idea being that the rapid movements of the ball and the players will induce movement of the clouds.

Of incantations used to avert hailstorms, Pliny asserts that he would not dare seriously to repeat the words, although Cato, in his work on agriculture, had prescribed a similar formula of meaningless words to cure the fractured limbs of animals. It may be interesting here to insert this remedy, which was found in a translation of some of the works of Cato and Varro by "A Virginia Farmer":

If a bone is dislocated it can be made sound by this incantation. Take a green reed four or five feet long, split it down the middle and let two men hold the pieces against your hips. Begin to chant as follows:

"In Alio. S. F. Motas Vaeta,
Daries Dardaries Astataries Dissunapiter."

and continue until the free ends of the reed are brought slowly together in front of you. Meanwhile, wave a knife above the reeds, and when they come together and one touches the other, seize them in your hand and cut them right and left. These pieces of reed bound upon a dislocated or fractured bone will cure it. But every day repeat the incantation, or in place of it this one:

"Huat Hanat Huat
Ista Pista Sista
Domiabo Damnaustra."

To protect crops from the ravages of vermin, Pliny says:

This I am sure upon mine owne knowledge, that there is an herbe (but what proper name it hath I wote not) which if it bee enterred in the foure corners of a field that is sowne with Millet, it will drive away Stares and Sparrows, which otherwise would by whole flights and flockes lie thereupon and doe much harme: nay I will speake a greater word and which may seeme wonderfull, There is not a bird of the aire one or other, that dare enter or approach such a field.

Among the European peasants we find many superstitious devices to propitiate or quell the vermin. Again quoting Frazer:

Amongst the Saxons of Transylvania, in order to keep sparrows from the corn, the sower begins by throwing the first handful of seed backwards over his head, saying, "That is for you, sparrows." To guard the corn against the attacks of leaf-flies (*Erdflöhe*) he shuts his eyes and scatters three handfuls of oats in different directions. Having made this offering to the leaf-flies he feels sure that they will spare the corn. A Transylvanian way of securing the crops against all birds, beasts, and insects, is this: after he has finished sowing, the sower goes once more from end to end of the field imitating the gesture of sowing, but with an empty hand. As he does so he says, "I sow this for the animals; I sow it for everything that flies and creeps, that walks and stands, that sings and springs, etc."

Again we are told:

The mouse is one of the most dreaded enemies of the rice-crop in Celebes. Many therefore are the prayers and incantations which prudent farmers resort to for the purpose of keeping the vermin from their fields. Thus, for example, a man will run round his field, saying, "Pruner is your name. Creep not through my rice. Be blind and deaf. Creep not through my rice. If you must creep through rice, go and creep through other rice." The following formula is equally effective: "Pruner is your real name. Mouse is your by-name. Down in the evening land is the stone on which you ought to sit; in the west, in Java, is your abode."

Another mode of getting rid of vermin and other noxious creatures without hurting their feelings or shewing them disrespect is to make images of them. Apollonius of Tyana is said to have cleared Antioch of scorpions by making a bronze image of a scorpion and burying it under a small pillar in the middle of the city. Further, it is reported that he freed Constantinople from flies by means of a bronze fly, and from gnats by means of a bronze gnat. In the Middle Ages Virgil passed for an enchanter and is said to have rid Naples of flies and grasshoppers by bronze or copper images of these insects; and when the waters of the city were infested by Leeches, he made

a golden leech, which put a stop to the plague . . . Gregory of Tours tells us that the city of Paris used to be free of dormice and serpents, but that in his lifetime, while they were cleaning a sewer, they found a bronze serpent and a bronze dormouse and removed them. "Since then," adds the good bishop, "dormice and serpents without number have been seen in Paris."

In Albania, if the fields or vineyards are ravaged by locusts or beetles, some of the women will assemble with dishevelled hair, catch a few of the insects, and march with them in a funeral procession to a spring or stream, in which they drown the creatures. Then one of the women sings, "O locusts and beetles who have left us bereaved," and the dirge is taken up and repeated by all the women in chorus. Thus by celebrating the obsequies of a few locusts and beetles, they hope to bring about the death of them all.

Amulets had a place in agriculture as well as in the general life of the people. The agate was considered an agricultural amulet, and it was recommended that it be attached to the plowman's arm and the horns of the oxen. Plutarch tells of a sort of poppy which grew in a river of Mysia and bore black, harp-shaped stones which the natives gathered and scattered over their ploughed fields. If these stones then lay still in the fields a barren year was signified, but if they flew away like locusts, a plentiful harvest was forecast. Pliny ascribes to the powers of stones such virtues as to benefit public speakers, admit to the presence of royalty, counteract fascination and sorcery, avert hail, thunderbolts, storms, locusts, and scorpions; chill boiling water, produce family discord, render athletes invincible, quench anger and violence, make one invisible, evoke images of the gods and shades from the infernal regions. In the thirteenth century Vincent, of Beauvais, medieval encyclopedist and author of *Speculum Maius,* stated that agates would avert storms and thunderbolts, give victory in war, rout venomous animals, aid the sight, slake the thirst and promote fidelity. He further said that the *balagius* would stimulate conjugal affection, burn the right hand grasping it, strengthen weak eyes if one drinks water in which it has lain, and protect against enemies. Coral is said by him to check hemorrhage, reduce corpulence, draw harmful humors from the eye, etc. Suspended from trees or sown with seed he believed it would protect the fruit or crops from hailstorms.

Astrology also had its place in agriculture. Pliny says:

Howbeit, wee cannot chuse but confesse, that the true reason and knowledge of agriculture, dependeth principally upon the observation of the order in heavenly bodies. Certes, a hard peece of worke it is, and infinite; and small hope I have that ever I shall be able to drive into their heads that are so ignorant and grosse of conceit, this high learning and heavenly divinitie as touching the planets, the fixed Starres, together with the reason of their orderly motions and coelestiall powers: Howbeit considering the great profit that may arise and grow thereupon to mankind, I will cast a proffer and give the attempt to make ploughmen Astrologers, or Astronomers at leastwise, if it may be.

Democritus, Pliny tells us, was able to corner the olive crop by his knowledge of astrology (which he calls astronomy) and "put to shame business men who had been decrying philosophy," and on another occasion to give his brother timely warning of an impending storm.

Probably the most numerous and elaborate agricultural festivals were celebrated at planting and harvest time, although there are many instances of magical practices performed by herdsmen and farmers at all periods of the year, and it is safe to say that no nation has been without its annual agricultural rituals. Space does not permit a description of these elaborate ceremonials, many of which have been practiced among the peasants in all parts of Europe even up to the beginning of the nineteenth century. They include the rites performed on Plow Monday in England; Shrove Tuesday in various parts of Europe, with carnivals similar in type in Bulgaria and other Thracian prov-

inces; and the fire-festivals practiced throughout all the area between Ireland and Russia and from Norway and Sweden to Spain and Greece. There were Lenten Fires, Easter Fires, Midsummer Fires, Hallowe'en Fires and Midwinter Fires, even the latter having an agricultural significance. The bringing of the Yule log is still solemnly observed by the southern Slavs, who seem to think that they will have as many calves, lambs, pigs and kids as they are able to strike sparks from the burning log. In some places a piece of the log is carried out to the fields to protect them against hail. There was also a "need fire," also called "wild fire" or "living fire," which was denounced in the eighth century by the Churches as a heathen custom, but which continued down to the first half of the nineteenth century in parts of England, Scotland, Ireland and Germany.

This custom of kindling great bonfires, dancing and leaping over them and driving cattle through or round them, together with processions or races in which blazing torches were carried round fields, orchards, pastures or cattle stalls, was believed to promote the growth of crops and the welfare of man and beast, either positively by stimulating them or negatively by averting dangers and calamities, witchcraft, blight, mildew, disease, etc. The "need fires" were resorted to especially when the cattle were attacked by an epidemic disease but were used whenever distress or calamity threatened.

The North American Indians also had their elaborate festivals, among which were the *busk* or festival of the first fruits, lasting eight days, and the Green Corn Dance of the Seminole Indians of Florida, which lasted many days and continued into the nineteenth century.

Dancing occupied a prominent place in all the ceremonials, and there was a common belief apparent in widely separated countries that dancing with high leaps and jumps would stimulate the crops to grow as high as the dancers leaped.

Magic, however, was not always believed to be practiced with beneficent intent, and consequently there is the paradox of magic being practiced to counteract magic. Down to modern times in eastern Europe when cattle were turned out to pasture in the spring, festivals were held on the twenty-third of April, St. George's Day, to protect the animals against the machinations of witches, as well as the ravages of wolves and other wild beasts. Among the South Slavs the herdsman crowns the horns of his cows with garlands of flowers to guard them against witchcraft, and in the evening the garlands are hung on the doors of the stalls, where they remain until the next St. George's Day. Early in the morning of that day, when the herdsman drives the cows from the byres, the housewife takes salt in one hand and a potsherd with glowing coals in the other. The salt is offered to the cow, and the beast must step over the smouldering coals on which various kinds of roses are smoking. By this means the witches are deprived of all power to harm the cow.

Instances of injury to livestock by magic were cited in our own country as late as 1692, in the famous Salem witchcraft trials in Massachusetts when such men as Governor William Phipps and Increase Mather, president of Harvard College, gave credence to the charges that due to the anger of one Bridget Bishop a pig was "taken with strange Fits; Jumping, Leaping and Knocking her Head against the Fence; she seem'd Blind and Deaf, and would neither Eat nor be Suck'd . . . and sundry other Circumstances concurred, which made the Deponents believe that *Bishop* had bewitched it."[5] Figuring in the trial of Susanna Martin were the charges that

[5] Mather, Cotton, "The Wonders of the Invisible World," (London, 1862).

she caused fourteen oxen to rush into the Merrimac River, all of which were drowned but one; that because she objected to the exchange of a cow with her son she caused this tame creature to grow "so mad, that they could scarce get her along. She broke all the Ropes that were fastned unto her, and though she were ty'd fast unto a Tree, yet she made her escape, and gave them such further trouble, as they could ascribe to no cause but Witchcraft"; that the cattle of one Bernard Peache were bewitched to death; that another complainant had lost cattle in one spring to the value of thirty pounds, following her threats.

Any selection of examples of magic that might be chosen from the various fields of study would show the same trend in the mental processes through which humanity has passed on its road to civilization. In the very beginning, when the struggle for food was instinctive, the simple acts performed without reason by individuals became group habits, and group habits became established customs. Without means of communicating their experiences to each other, and consequently with no basis of knowledge, the various groups gained their beliefs from false inferences relating to any accidental happening; and since the greatest care might sometimes result in failure and calamity, and lack of care at other times result in good fortune, there entered the aleatory element, or the belief that good or ill luck was due to the agency of ghosts or spirits, dependent upon the pleasure or displeasure of the superior powers at the acts of man. It took hundreds of years to overcome such beliefs by the aid of reason and to gain the knowledge, step by step, that has made possible the agriculture of to-day. Even yet research work has much to accomplish in this as in all other branches of learning, and processes are still taking place in the replacement of false practices by acts based on scientific knowledge, for which research facilities are available to an extent unknown in any period of the past.

BIRDS AND OTHER CHECKS UPON INSECTS

By W. L. McATEE
U. S. BIOLOGICAL SURVEY

THE article by Professor E. H. Strickland in the SCIENTIFIC MONTHLY for January, 1928, entitled "Can Birds hold Injurious Insects in Check?" fails to acknowledge that it was arguments founded on the economic value of birds that made possible the present very satisfactory American code of laws for bird protection. Professor Strickland implies that he is one who would protect birds for humanitarian and esthetic reasons, and he should accordingly be pleased that they are at present so well protected, even though this condition was brought about mainly by economic considerations. He need have no fear that bird lovers are a dying race, in fact their number was never greater than at present, and bird protection can be effectively urged to-day for esthetic reasons which would, however, have had very little appeal forty or fifty years ago when the groundwork of American bird protection was being laid.

In the course of his article, Professor Strickland points out certain principles of natural philosophy, applying them in a restricted way to the relations of phytophagous insects, their parasites, and bird predators, but weakens the whole texture of his argument by failing to take into account the universality of their application.

The general principles as to the fecundity of insects pointed out by our author apply also to birds. If a bird of average size lays four or eight eggs yearly, it would if unchecked use up (its greater capacity considered) the available food supply, or on account of its greater bulk actually fill up the available space (due to the same inexorable geometrical progression,) and reach these limits in all probability just about as quickly as would an insect. All that, however, is merely theoretical, for the expanding groups meet competition in every direction and are checked by a multitude of adverse factors, so that their potentialities for increase are never realized. As a result of these great checking forces all but a very small proportion of each generation of a fecund species perishes, but the law applies throughout, whether to plant-feeders, parasites or what not.

Mortality statistics are the same for birds as for insects, or any other organisms, and barring fluctuations in the balance of nature there are only enough survivors of each species to replace the parent population. Among the factors causing the mortality of insects, those directly or indirectly due to climate are by far the most important.[1] It is an exaggeration to give parasites first rank, as our author does, among factors exercising general control over the insect population.

It should not be forgotten that essentially parasites are dependents. It is farthest from their object to exterminate their hosts, even in a limited area. This result, which in most cases means disaster to the parasite, is, on the other hand, of but little moment to predacious insects or birds. The latter always have a wide range of prey, and even if one food supply is exhausted usually there are others at hand. The best evidence that

[1] See Marlatt, C. L., Bul. 20, n. s. U. S. Div. Ent., 1899, pp. 73–76; Scott, W. M., *ibid.*, pp. 82–85; and Chittenden, F. H., Bul. 22, n. s., U. S. Div. Ent., 1900, pp. 51–64.

predacious foes of insects are worthy of as high consideration as parasitic ones is afforded by the instance of the extermination, successively, by the ladybird, *Vedalia cardinalis,* of the cottony cushion scale in California, of the fluted scale in South Africa, and of a congeneric scale insect in the gardens of Alexandria, Egypt. Lady-birds of the genus *Hippodamia* are used with great success in the control of injurious aphides in California. These are among the greatest successes that have been obtained in biological control and they have involved the use of predators, not parasites.

The statement by Professor Strickland, that "provided man does not upset the relationships between any plant-feeding insect and its parasites, the average population of that plant-feeding insect can never vary very extensively over periods of more than a few years," is applicable to almost any opposed relationship between organisms throughout the whole range of nature. It is not peculiar to insects and their parasites; the statement might read insects and their bird enemies, fishes and fish-eaters, insects and spiders, in fact almost any similar case and be equally true. Perusal of Dr. S. A. Forbes' paper "On Some Interactions of Organisms"[3] is recommended in this connection.

Again our author says, "We can not but conclude . . . that the annual destruction of plant-feeding insects by birds has no appreciable effect upon their ultimate abundance." This statement is just as applicable to every natural check: the word "parasites" can be substituted for birds in this statement and it will be just as true. The ultimate abundance is on the average the same, as our author himself repeatedly states in this paper.

Our author finally admits that birds eat parasitic as well as plant-feeding insects, thus undermining the highly artificial arguments he builds up on the premises of selective destruction of phytophagous insects by birds. As a matter of fact, birds as a whole tend to apply indiscriminate pressure on the insect race, cutting them down in proportion to their numbers, work which in its indiscriminacy parallels that of all factors of natural control combined, which tends to preserve the balance of nature, so called, and is therefore good.

Professor Strickland quotes from Rondani that "the policing of fields can not be entrusted to birds because they are unreliable and kill the guilty with the innocent." It is almost inconceivable how entomologists can make such statements as this and not see the implied condemnation of their own most effective methods of combating insects. Stomach poisons result in the death of any parasites contained in the bodies of hosts feeding upon them, contact poisons kill friend and foe alike, fumigation with poisonous gases is indiscriminate in its effect. Nevertheless, these are the principal weapons of the economic entomologist. They do good, are effective in securing the degree of control we need for crop production, have long been used and will continue to be used. Their effectiveness proves that a general reduction in the number of insects, useful along with the harmful, has a satisfactory net result, and is in effect a strong endorsement of the utility of birds whose combined activities against insects tend to be indiscriminate. One eminent entomologist who sees the truth in this respect, Paul Marchal, says: "However useful the parasites may be, the fear of destroying them ought never to prevent the taking of all measures having for their object the direct destruction of harmful insects"; and with regard to birds, "the protection of in-

[3] Bull. Ill. State Lab. Nat. Hist., I, No. 3, 1880.

sectivorous birds appears to us not at all susceptible of thwarting the beneficial action of useful insects."[3]

Professor Strickland asks the question, "Can birds hold injurious insects in check?" and his answer is, "It is improbable that in the case of the vast majority of plant-feeding insects, birds are a factor of much importance in reducing their population." In this connection let us quote two sentences from earlier portions of his paper: "We all know, however, that, with comparatively few exceptions, each of our numerous kinds of insects is present in approximately the same numbers from year to year." . . . The relative number of eggs that are laid by different species of insects has surprisingly little effect upon their annual abundance," and there are other expressions certifying to the normal year to year stability in numbers of the insect population. These statements mean that no agency permanently reduces the population, and place parasites as well as other checks on insect abundance in the same category Professor Strickland attempts to assign exclusively to birds. As a matter of fact, insect control aside from that applied by man is due to a combination of all inimical factors—unfavorable manifestations of climate, activities of predators, and parasites, of both the animal and plant worlds, and failures due to constitutional defects in the insects themselves—in a word to the whole environmental complex. Little is gained by discussion of the relative value of the various biological factors, while much risk of error is incurred.

With regard to birds, it may be said that economic ornithologists gauge the usefulness of birds more on their general tendencies than on specific activities. These scientists do not make exaggerated claims of the sort alleged by Professor Strickland. They recognize that the most useful function of birds lies in their constant cutting down of the numbers of insects in general, and not in their more spectacular services in the presence of insect outbreaks.[4]

At the same time we need not hesitate to point out certain features of insect control by birds that entitle them to special appreciation. Birds have the advantage of stopping the feeding of an insect victim at once; parasitized, the insect may continue feeding and possibly consume more than the normal amount of food. Birds are not so much affected by climatic factors as are parasites and do not require two or three years as do parasites after every setback to again apply effective pressure on the numbers of their prey. When harmful insects are introduced into the country, it may be years before parasites become adapted to them, or we may be compelled to import parasites; birds can and usually do feed upon them from the first. Birds are a mobile force against insects and gather at the scene of an insect outbreak. If the latter is local a bird population several times the normal for the area may assemble and feed upon the insect to a much higher than usual extent, and there are numerous records of birds actually extirpating such local infestations.[5] No one claims that birds can control widespread outbreaks of insect pests nor do we observe parasites so doing.

However, there is no necessity for belittling the services of either of the two great classes of pest destroyers. Both consume a certain proportion of insects directly injurious to man, and it is more than likely that either would be hind-

[3] Ann. Inst. Nat. Agron., 2e Ser., T. VI, 1907, pp. 298–299.

[4] Beal F. E. L., "The Relations between Birds and Insects," Yearbook, U. S. Department of Agriculture, (1908) 1909, pp. 343–350.

[5] McAtee, W. L., "The Rôle of Vertebrates in the Control of Insect Pests," Smithsonian Rep. (1925) 1926, pp. 415–437.

ered rather than helped by the absence of the other. Everything, indeed, points to the conclusion that from the standpoint of man's welfare the loss of either class would irreparably disturb the balance. What has been said by a noted entomologist concerning parasites, namely, that the presence of both parasites and hosts, continuing through thousands of years to the present, implies that an equilibrium is maintained, enabling each to live, is just as true of predacious enemies, both in relation to parasites and to their common prey. There can be no doubt that, even under the greatly changed conditions induced by man, the inter-actions of these classes tend directly toward the establishment and maintenance of a balance. It is probable that this balance can be secured at a lower level in regard to number of individuals only by direct reduction of the injurious species by man, coupled with the best possible protection of both their predatory and parasitic enemies.

Birds are one of the natural forces regulating the numbers of insects, and it takes all of them combined to do the job. In fact, even all of them together can not do it as we should like, and it should not be forgotten that, regardless of birds, parasites or other natural checks, it will as a rule be necessary under the artificial conditions he has created, for man to combat insects directly in order to secure the degree of control necessary to commercial success.

SPECIALIZATIONS GOVERNING MUSICAL EXPRESSION AMONG INSECTS

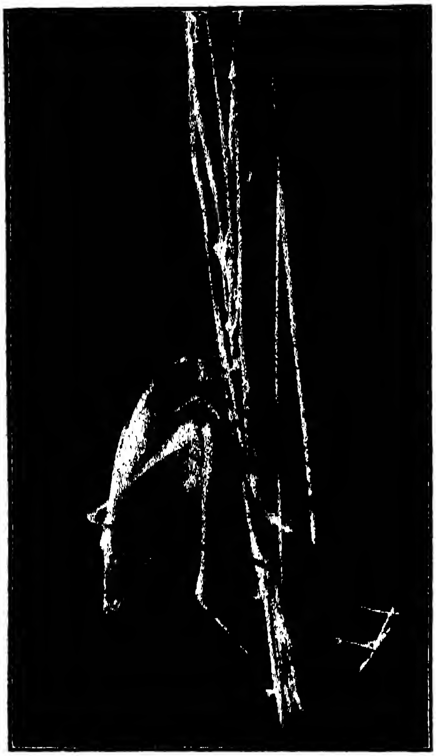
By H. A. ALLARD

U. S. DEPARTMENT OF AGRICULTURE

AMONG the birds it is well known that musical expression has reached a high degree of development, as attested by the masterly singing of our own thrushes, the wood thrush, the veery and the hermit thrush. The birds, however, have specialized in vocal music. Nature has made them the spontaneous vocalists of earth whom none excel. The distinctive instrumentalists of earth are our musical insects, and they have learned to do their humble part well. In the sense of singing through the buccal cavity, no insect possesses a voice. The cicadas or harvest flies, so called, sing within special cavities of their bodies and to this extent come nearer being true vocalists than our crickets and katydids. In the music boxes of the cicadas thin chitinous membranes are at will set in rapid motion by a very powerful and efficient musculature. Not having lungs and throat adapted to vocal singing, the majority of our musical insects have developed external frictional structures wherever contiguous surfaces naturally approach each other and can be rubbed together at will. When we consider all the insects as a class, scarcely any part of the body has been overlooked. It would seem that every movable chitinous surface of the external insect body capable of rubbing upon another part is potentially a musical organ. Strange it is that in some great groups remodelling and sculpturing to produce file-vein and scraper or plectrum has been so consistently followed. It is incomprehensible that this specialization should arise unconsciously, spontaneously as the refinements of crystalline structures in inanimate matter appear to arise: it is as equally incomprehensible to see how the consciousness of life should evolve and shape its trend. No philosophy of life explains it but it is there, and it appears to be as deep a riddle as life itself.

Marvelous specializations for making sounds have evolved among the beetles, and have arisen on nearly every part of the body where two adjacent surfaces can be brought together. They have arisen upon the head, the mandibles, the pronotum, the mesothorax, the fore legs, the middle legs, the abdominal segments, the elytra or wing-covers. It would appear that in practically all types of frictional stridulation the typical structure is concerned with a file-vein and scraper to be drawn across its teeth. However, many simpler structures apparently less refined may also be found as merely roughened surfaces, ridged or tuberculate. The mysterious forces of life appear to be not always content with mere simplicity, and once a tendency arises, specialization and elaboration may be expected to unfold, to almost any degree of refinement.

As yet, characteristic of the beetles and possibly some of the ants alone, so far as known, it would seem remarkable tendencies have been shown. We have spoken of the simple file-vein, which corresponds to the teeth of a comb, as a sound-producer. It is evident that the teeth of this microscopic file or rasp are the rigid strings, so to speak, of this natural insect violin or mandolin. Some beetles, strangely enough, have been generously equipped with two file-veins and



UHLER'S KATYDID (*Amblyoorypha uhleri*) MALE. THIS LITTLE KATYDID HAS A VARIETY OF LISPING NOTES. ABOUT NATURAL SIZE.

even with additional accessory musical structures in some instances, so that veritably are they musical adepts on more than one instrument. It is a marvelous elaboration among the lowly insects, but that is not all. Nature with the organic magic of her cosmic touch has elaborated the simple file-veins in a masterly way. She has made them with fine teeth in one part and coarse teeth in another. On the file-veins of a few beetles she has even produced three sets of teeth, coarse, medium and fine. What does this mean? It probably means that at least three distinct sounds may be produced at will, with variations of loudness and pitch or shrillness. Here would it seem the insects are breaking away from the monotony of a single note, and have in mind the production of several notes, or perchance a primitive scale like the birds with their vocal chords. There is something deep and significant in these trends and specializations of the organism playing with sound, seizing upon it to make it a part of its conscious experience at last.

While the beetles show many elaborations indicative of sound sensitization and sound-consciousness, very little is known of the actual sounds they produce, because they are too far removed from the everyday experiences of the human ear to receive much attention. For this reason not much poetry is going to arise soon glorifying the singing of the beetles. Fortunately we have another order of insects which are instrumental musicians of the highest stamp, the Orthoptera, including all our musical grasshoppers, katydids and crickets. Many of these are large enough to be heard in everyday life, and many of them have with merit sung their way close to our hearts and moods, so that much of our poetry savors of their presence. This is well, for who does not love the chirping and purring of our crickets?

Profoundly musical are these dainty creatures, perhaps more truly musicians from the pure love of sound for its sake than the beetles themselves. I do not call an insect a disinterested musician that sings merely to call its female to it, or because it wishes to terrify something, as we have explained it rather glibly, but because it sings for no other reason than that it loves sound and the pleasures of sounds, as do we humans. The utility theory, so glibly invoked by Darwin and others to explain all the musical moods of insects, will not stand the test of close scrutiny. There are other reasons back of the mood than the enticements of sex, etc., just as among the birds and among humans. There is just as good reason to believe insects find pleasure in their sounds as do humans

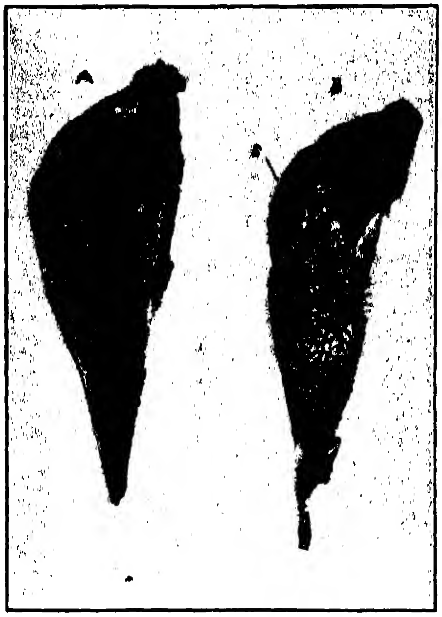
in theirs. Simple as the sounds of insects appear, oftentimes little more than rasp and rhythm, one must not forget that the beginnings of man's primitive music were scarcely more than sound and rhythm; and, let me add, oftentimes not much better is much of our modern music to-day.

The fundamental principle of a file-vein and scraper with few exceptions is found among all the grasshoppers, katydids and crickets. It appears to be the universal principle of musical evolution in the development of nearly all insect instrumentalists, except the cicadas, yet what else could the living impulses well seize upon to modify in the direction of instrumental music? The forces of life seem to have well recognized this, and the file-vein is the type of all frictional music. It may and does appear on a variety of structures, being upon the hind legs or upon heavy veins of the wing-covers in our own true grasshoppers. In our own commoner katydids and crickets, however, the position is quite consistently at the base of the wing-covers alone.

So far as known, the crickets and katydids have not given especial attention to modifications of different portions of the file-vein, as have the beetles. Yet as I shall show, specializations of the musical impulse and touch and time-relations have been profoundly elaborated just as among the birds with their vocal music.

First we may consider the matter of musical tone or pitch among insect musicians. Almost without exception, the grasshoppers and katydids merely rasp or scrape out noise of one quality or another, loud, rasping or soft, silken, lisping. At no time is it characterized by musical pitch or tone. The crickets with the same type of file-vein have somehow gone immeasurably beyond the katydids by developing true tonal music or pitch, and they have done this as a great group. It is a marvelous forward step in the evolution of genuine music, and to be genuine music for the human ear, tonal-quality must come into the component sounds. Who shall say there has not been an upward trend here consciously or unconsciously, organically or inorganically, as we please to regard it? It is a mistake, however, to think the human ear is the only criterion of music in the universe. The mere noise of the katydids may have the fundamental elements of music in it as truly as the tonal sounds of the crickets. To the katydid ear analysis of their own sounds may be as acute as our ears for our own more musical tones. As a matter of fact my own ear can detect wide variations of quality in the clicks struck off by the larger angular-winged katydid in using the single teeth of its file-vein.

This is the first point in our analysis of the musical impulses of insects. We will now go back to the katydids, with their strident lisps and rasps, and see what they have done with simple file-veins and scrapers in evolving the formalisms of music. There was a time when I regarded the abilities of the katydids as of a simpler, lower order of specialization than the crickets, because the crickets had evolved tonal quality, and the katydids only noise, sound. I have been led to change my mind. It is evident that specialization may proceed in more than one direction. In the case of the beetles, elaborations and refinements of the teeth of the file-vein have taken place: In the case of the crickets the great forward step has been the acquirement of musical pitch. In the case of the katydids evolution has been in the direction of a better control or manipulation of the musical structures and a consequent specialization in the direction of variety of notes. In this behavior the katydids have gone far ahead of the crickets in spite of their momentous tonal accomplishments. It was a



MUSICAL ORGANS OF THE LARGER ANGULAR-WINGED KATYDID (*Microcentrum rhombifolium*). A. FILE-VEIN ON UNDER SURFACE OF UPPER TEGMEN. B. SCRAPER—A CHITINOUS RIDGE AT S, SITUATED AS THE UPPER EDGE OF THE LOWER TEGMEN. MAGNIFIED ABOUT 10 TIMES.

wonderful step to leave mere noise behind and seize upon tone. Yet if the crickets had kept pace with the katydids in the evolution of a better manipulation, they would now have been playing simple tunes almost, like some of the birds with their vocal art.

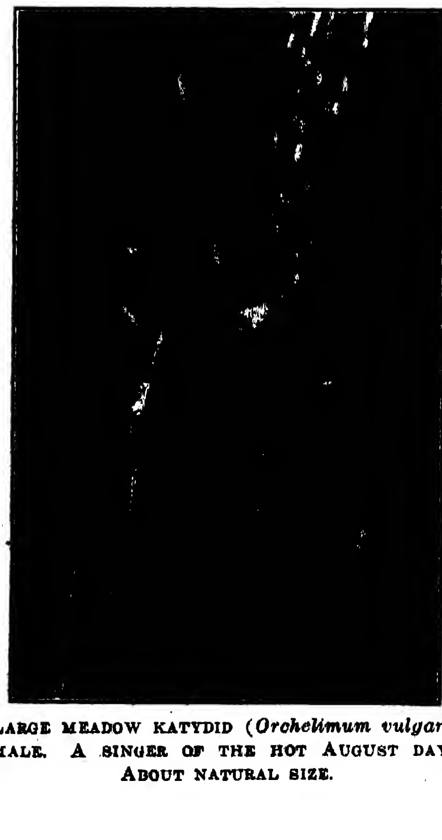
There is every degree of musical expression among the katydids. Some of the cone-headed katydids (*Neoconocephalus*) merely set their wings humming in a continuous buzz of monotonous sound, perhaps the simplest musical expression, for not even rhythm is involved. The next step is to break up this simple monotone into rhythmic intervals, and some cone-headed katydids do just this. They do it with an astounding uniformity—slower with cool temperatures, faster with high temperatures. These rhythmic rasps or beats are a substantial advance in music evolution, it would seem. They mark the earliest beginnings of definite musical expression. Among men as well is this true, for primitive men cared as much for the pure rhythmic beat as for anything else. Burton, speaking of the music of African savages, said they would sit for hours at night chanting with an untiring mood. a ceaseless repetition of a few notes or lines. Let me add that our musical insects as well as men have an inherent ear for simple rhythm. Gurney has said "The fact of the love of mere rhythm and repetition among uncivilized people seems nearly universal." But this love of simple rhythm goes back even to the crickets themselves: it is not a characteristic of the lives of men alone.

Such were the beginnings of man's music, and such is much of our insect music to-day, an irrepressible mood for the mere rhythmic repetition of sound. It would be a real step forward to break away from this almost inanimate mechanical rhythm, and some of the katydids have done this. The big meadow katydids of the genus Orchelimum have introduced variety into their mechanical "songs." They have done it by varying the notes and phrases in more or less definite ways, establishing new time-relations and sequences of sound. The typical Orchelimum song begins with a series of short staccato notes, then runs off into a long lisping monotone. It may be represented thus: *zip-zip-zip-zip-zeeeeeeeeeeeeee, zip-zip*-pause, *zip-zip-zip-zip-zeeeeeeeeeeee, zip*. This song has very much of the stamp of the grasshopper sparrow's simpler song or lisping monotone. It is evident that it has more variety and complex time-relations than the simple rhythmic *zip-zip-zip-zip* repeated for long hours by some cone-headed katydids.

One of the most remarkable songs is that of the little Uhler's katydid (*Amblycorypha uhleri*) common in the Washington region. There is even more

variation in the complete expressions of these katydids than in the songs of the Orchelimums. These complexities denote specializations in the direction of variety. Some weird evolving principle is at work upon their songs, breaking up the basic, eternal rhythm into something finer, more prolonged, more varied, analogous to the refinements and specializations shown by the finer singers among the birds. Strange to say, these specializations have gone much farther among the noise-rasping katydids than among the tone-loving crickets, for as yet the latter still cling to the simple monotone or the more or less regular, rhythmic chirp. In not one instance, at least among our eastern crickets, have they shown the elaborations toward new complexities of expression characteristic of some of the katydids. The little Uhler's katydid begins its song with a prolonged, soft, lisping sound, produced by a rapid shuffling of the wings. This soon runs into a succession of short staccato lisps *zip-itsip-itsip-itsip-itsip*—and ends with a rapid shuffling sound, several times repeated—*sh-sh-sh-sh*. The entire song may be expressed thus: *s-s-s-s-s-s-s-sip-itsip-itsip-itsip-itsip-sh-sh-sh - sh———sh-sh-sh-sh———sh - sh - sh - sh*. Sometimes additional staccato notes, *tip-tip-tip-tip*, are added to the final lisping phrases.

This is a remarkable elaboration as compared with the brief, monotonous, recurring zips of a cone-headed katydid or the simple chirps of a cricket. It is evident that much more can yet be done with a simple file-vein with teeth, operated upon by a plectrum or scraper. There are many teeth on the file-vein depending upon the species of insect-musician. Some may have around fifty to sixty teeth; others may have one hundred to several hundreds. In practically all instances, the scraper is drawn entirely across this vein to produce one rasp or backwards and forwards several times to produce a single chirp or rasp. However, there are additional possibilities here, one being the selection of one or more teeth to produce a single note or tone. Remarkable as it may seem, one katydid, the larger angular-winged katydid (*Microcentrum rhombifolium*), has somehow learned this potentiality and has specialized upon it in a unique way. This katydid has two distinct notes, one a loud, keen zip, made by opening the wing-covers and bringing them suddenly together. In this movement the scraper passes over the entire file-vein as one would draw a knife-blade smartly over all the teeth of a comb in one quick brief draw. The other "song," perhaps the only true "song" of the species, shows a remarkable manipulation of the scraper over the file-vein. The upper edges of the wing-covers are separated as far as possible, perhaps three sixteenths of an



LARGE MEADOW KATYDID (*Orchelimum vulgare*) MALE. A SINGER OF THE HOT AUGUST DAYS. ABOUT NATURAL SIZE.

LARGER ANGULAR-WINGED KATYDID (*Microcentrum rhombifolium*) MALE. FINEST OF ALL OUR KATYDIDS. IT HAS LEARNED A MARVELOUS TECHNIQUE WITH ITS ALMOST MICROSCOPIC CHITIN XYLOPHONE.

inch, then allowed to close with such a nicety of judgment that the scraper, striking only one or more teeth of the file-vein at a time, produces a series of from twenty to thirty or more loud leisurely clicks, becoming more rapid toward the close until the wing-covers have been brought entirely together. So far as the writer's observations go no other katydid and none of our crickets has acquired this nicety of judgment and touch in their musical expressions. The file-vein of this katydid possesses about fifty-five to sixty teeth if one includes every reduced tooth at each end, or perhaps not more than forty to forty-five well-developed teeth. If thirty to thirty-five notes were produced in this single closing operation of the wing-covers, it is evident that not more than one or two teeth could be involved to produce each click. This to my mind represents a remarkable understanding and manipulation of the simple mechanical features of the musical file-vein. It is the first evidence which we have that perhaps the musical insects are working toward simple melody, as the birds have done. As a matter of fact, the separate clicks of this katydid show marked variations in volume and pitch to the trained ear, even though it is not a sound with musical pitch, such as human ears appreciate. If the crickets have made a momentous step forward with the production of musical tones in place of rasping noise, this katydid has attained a remarkable specialization and skill in technique dealing with the primitive rasp. Should now the crickets attain this same technique with their file-veins, we would have a veritable series of musical tones capable of enough variation in pitch by further elaboration to produce the simple melody, and quite as efficiently as the birds have done with their vocal chords.

With the musical impulses of life in the field of instrumentalism specializing upon the file-vein, the character of the file-vein and its teeth and the matter of technique in using this are the two potentialities alone which would be involved. It is evident that the insects are showing unmistakable trends in both directions. Some of the beetles and perhaps the ants have gone far in elaborating the structures of the file-vein; some of the katydids have hit upon a highly specialized and skilful technique. Finally, the crickets have hit upon tonality such as men pronounce good from the point of view of their own musical sensibilities. These are the indubitable facts. What they mean we know not, nor never will, perchance. However, it is plain that sound-sensitivity is one of the elemental characteristics of life as truly as light sensitivity. Men merely share the same musical tendencies with countless other forms of organic expression.

The crickets and the katydids are the great insect instrumentalists of earth, as much impressed with sound rhythms as are we and even with tonality, it would

seem. Perchance they are but passing along the mysterious musical ways of men in some weird, organic, cosmic trend toward a fuller appreciation of sound, involving pleasurable sequences of tone, time-relations and tonal combinations which we call music. Our own musical specializations rest upon the same elemental foundations that the insects and the birds make use of. Rhythm is as much within their mood as within ours. The file-vein of the cricket is but a microscopic many-stringed mandolin, so to speak, or perhaps more correctly speaking a xylophone with parallel resonant chitin bars comparable to the resonant pieces of wood of different lengths arranged to produce the tones of the xylophone. The xylophones of men are but larger file-veins which they make but which will not grow naturally upon the integuments of their backs or legs. It would be just as easy for the deep cosmic intelligences of life, of which we know nothing, to fashion the simple file-vein or natural microscopic xylophone of the cricket into one with a scale of simple tones as for the birds to do it with their vocal chords. If our tales of evolution are really true, the birds have done it, and the hermit thrush is an outstanding virtuoso of this evolution from mere lowly reptiles.

The birds have gone far in their musical evolution, but upon the same basic principles observed to-day by our musical insects. The primitive scale is within the bird's soul. F. Schuyler Mathews has written: "But of serene, exultant melody in the music of the birds there is plenty; the plainest evidence of it is in the songs of the thrushes, and we have convincing proof that their music is built upon definite, primitive scales—scales which the birds used eons of years before man did."

There is another feature of insect music, not at all understood but resting upon the basic foundations of their internal sense of rhythm. I speak of the synchronous rhythm characteristic of the singing of certain chirping tree crickets, the snowy tree-cricket (*Oecanthus niveus*). Many crickets sing with regularly delivered notes; others do not. They sing with the mood of rhythm in their souls. More than this, some species, singing in company, sooner or later prefer to adopt the same time relations and chirp in unison. Now do we have a marvelous group synchronism, each chirp the "rhythmic beat" of the multitude. It is a keeping time and step and nothing more. It is no figment of the imagination, but a fact observed by men of science and reported by Fulton and others.

What it really means we do not know, but these famous snowy tree-crickets strive to keep time, and appear to sing more at their ease when they can do so,

SNOWY TREE CRICKET (*Oecanthus niveus*) MALE. THE POET'S CRICKET, WITH A LOVE OF RHYTHM IN ITS SOUL EVEN AS MUCH AS MEN.

based on some peculiar law of internal rhythm governing their musical makeup. I have made some studies of this question, and have found that a cricket, chirping at a certain rate per minute, will actually hurry his notes or change their rate to adopt a slightly different rate of mimic chirp to which I subjected him. All these features of musical expression are deep-seated elemental moods of life, governing not alone the music of insects, but the seemingly more conscious musical specializations of men.

It is strange that although the birds as a class are vocalists, even they have turned to various forms of instrumentalism, as well as the insects. The ruffed grouse beats a soft, thrumming tattoo upon the air; the snipe has learned to bleat with its tail-feathers in a rapid descending flight, and the night hawk has learned to twang a boom loudly upon the atmosphere with its wing pinions in a terrific far-flung drop to earth. Even a Turkestan lizard has learned to produce a cricket-like shrilling with certain modified scales or plates upon its tail.

These all represent the same strange unaccountable strivings of life after ways of producing sound, because somehow sound affects the organism strangely, weirdly and seems necessary to its well-being and pleasures of existence.

The organism, it would seem, is as sensitive to the ubiquitous sound-waves as to light-waves, and in the case of the katydids and crickets would analyze them and wear them upon their backs, as some analyze and wear the light upon their integuments in varied patterns and colorations. There are strange organic analogies here between the responses of life to sound-waves and to light-waves. Those fundamental organic moods, responding to the sound-waves so aptly and adroitly, seem as spontaneous and as unconsciously originated and regulated oftentimes, as the external integuments to the disposition of the light falling upon them. Specialization somehow subtly takes hold of life and all the potentialities of life, till the organism feels the growing consciousness of its refinements, and henceforth consciously directed behavior seems to come in. There is much to be learned concerning the specializations of the musical interests. As yet it is a great, almost untouched department of science. Although musical insects occur in practically all parts of the world where plant life is found, unfortunately very little is known of the musical behavior of this great group of insects. It can not be considered a trivial and unworthy subject of scientific study, but one as broad and as complex as the vocal singing of birds. There are questions of fundamental importance in the matter that deserve to be examined, concerning the insect's ear for sound, for rhythm, synchronism, tonality, etc. It is quite probable that a complete survey of all the musical tendencies and behavior of the musical and sound-producing insects of the world would throw much light upon the fundamental musical concepts and tendencies of man himself, for common irrepressible laws seem to govern the musical moods of their lives.

THE PROGRESS OF SCIENCE

HIDEYO NOGUCHI

1876–1928

In 1900 Dr. Hideyo Noguchi joined the staff of the department of pathology at the University of Pennsylvania as a volunteer. His interest in bacteriology had already manifested itself, for in 1898, very soon after his graduation from the Tokyo Medical College, he became assistant at the Government Institute of Infectious Diseases, of which Professor Kitasato was the director.

Dr. Noguchi's coming to Philadelphia was quite fortuitous. The writer stopped in Japan on his way to Manila, and chance threw him and Dr. Noguchi together. Noguchi remained at the University of Pennsylvania for four years, and then accompanied him to New York, to become one of the small group composing the original scientific staff of the Rockefeller Institute.

It was during the Philadelphia period that Noguchi's exceptional gifts as an investigator manifested themselves. The investigation of the venoms, pursued from the standpoint of the newer knowledge of toxins and antitoxins which Ehrlich's brilliant theoretical generalizations had done so much to increase, yielded a rich booty. The choice of the venoms for study was in turn influenced by Dr. Weir Mitchell's earlier important investigations on snake venoms. Dr. Mitchell was instrumental in supporting the undertaking, at first personally and later through the interest he aroused in the National Academy of Sciences and the Carnegie Institution of Washington.

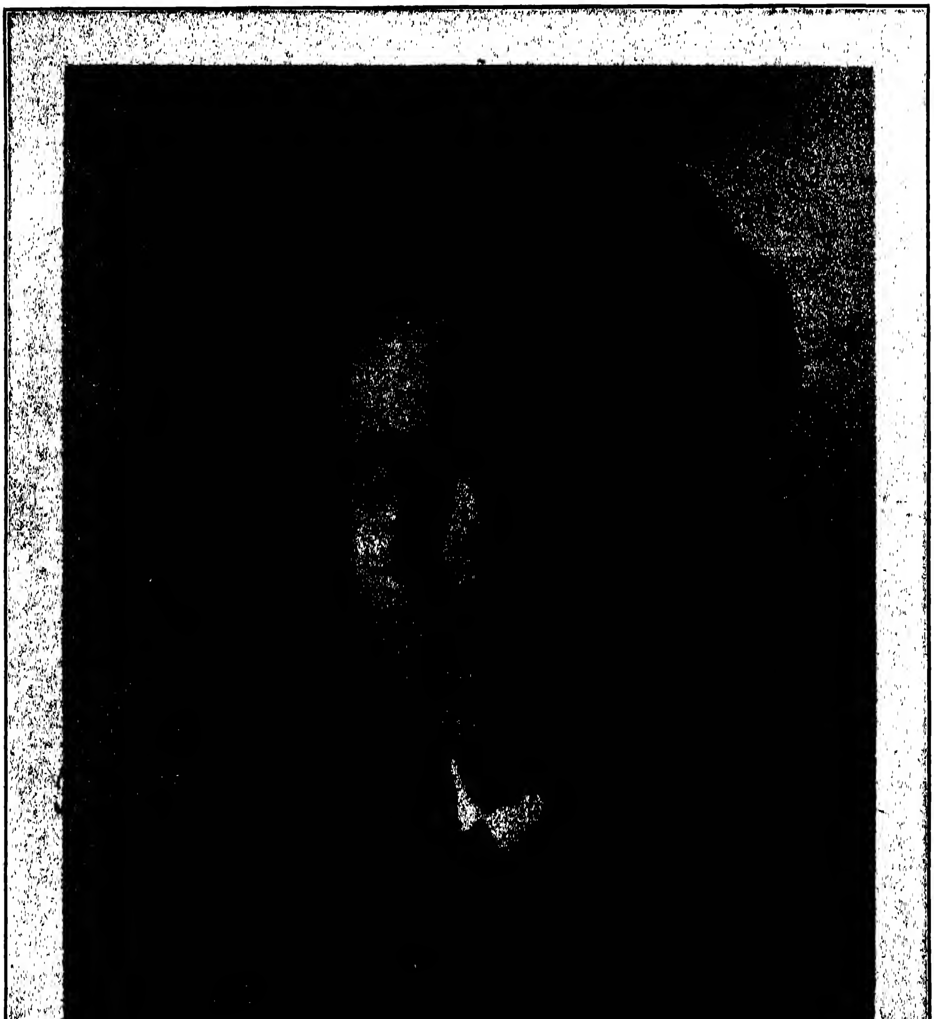
At the Rockefeller Institute, Noguchi devoted himself in particular to the investigation of unusual microorganisms and diseases of unknown origin which they induced. His rewarding studies on spirochetae, a number of which he cultivated artificially for the first time, form a model piece of bacteriological research. Among those obtained in pure culture is *Treponema pallidum*, the incitant of syphilis. Others include the spiral microorganism of relapsing fever and African tick fever. Besides these he cultivated many mouth and other spirals for the first time.

We owe to Noguchi the finding of the syphilis spiral in the brain of paretics, a demonstration which lifted this serious disease from an inferential to an established position in the list of syphilitic infections. This finding was a feat of observational acumen comparable with Schaudinn's detection of the pallidum in the lesions of syphilis.

In 1915, profiting by his work on the spirochetae, Noguchi purified vaccine virus from associated bacteria by cultivating it in the tissues of rabbits. This method of securing bacteria-free virus for vaccinating human beings is now being widely employed.

In 1918 Noguchi made the first of four expeditions to South America to investigate yellow fever. He accompanied the commission sent by the International Health Board of the Rockefeller Foundation to Guayaquil and isolated *Leptospira icteroides* from six of twenty-seven cases of yellow fever. On subsequent expeditions to Mexico, Peru and Brazil he cultivated the same organisms from cases of yellow fever in those countries.

Recently Noguchi isolated *Bartonella bacilliformis* from cases of Carrion's disease (oroya fever) and verruga peruana, and thus established the relationship of the two conditions previously controverted. By employing cultures for inoculation into *Macacus rhesus* he repro-



HIDEYO NOGUCHI
IN HIS LABORATORY AT THE ROCKEFELLER INSTITUTE

duced the two pathological conditions representative of the two natural diseases.

In 1926 Noguchi accomplished the cultivation of a new bacterium from the eyes of American Indians, which on inoculation into the conjunctivae of *Macacus rhesus* and chimpanzees reproduced the lesions of trachoma as they exist in human beings. A monograph describing in detail the work on trachoma was completed just before he sailed for Africa; it is in press and will soon be published.

Noguchi died of yellow fever at Accra, on the Gold Coast, West Africa, on May 21. The expedition to Africa was undertaken for the Rockefeller Foundation, because the results of his investigations of yellow fever in South America proved inapplicable to the disease as it exists in Africa. His African investigations were virtually completed when he was himself sticken with the disease. The results of his studies will not be lost, as they are described in letters, and his notes and materials have been carefully preserved.

Noguchi was an international figure, much respected and beloved. His premature death is a great catastrophe, and messages of sorrow and sympathy have come from many lands. His name is to be associated with the great investigators who founded bacteriology and have placed it so securely among the experimental sciences.

SIMON FLEXNER

Edgar F. Smith
5/25/1926

EDGAR FAHS SMITH

1854–1928

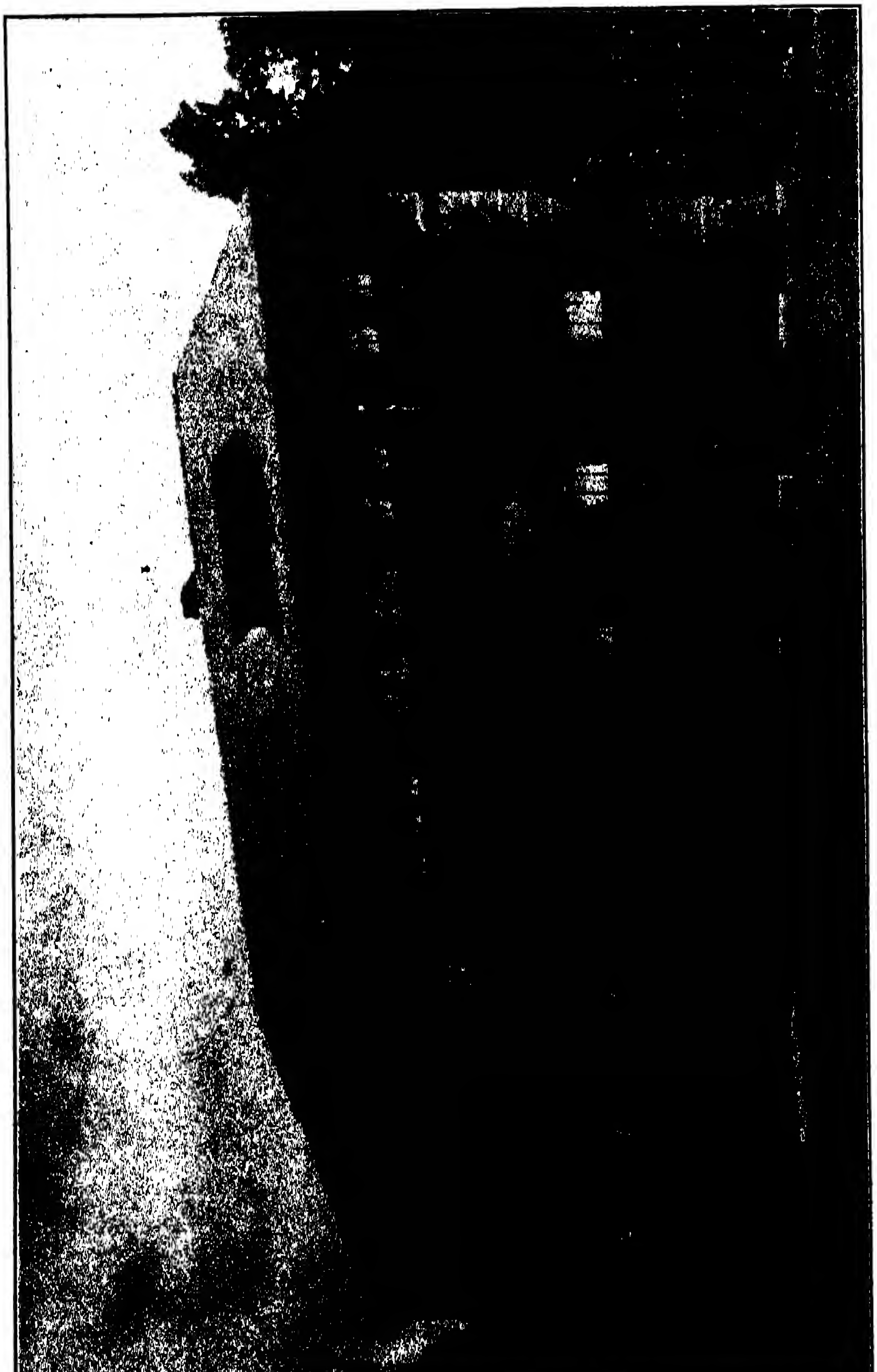
CHEMISTRY in America has suffered an irreparable loss through the death of Edgar Fahs Smith, which occurred on May 3 in the University of Pennsylvania Hospital. Even outside of his chosen profession and beyond the limits of his native country the news of his demise will occasion keen regrets, for Dr. Smith enjoyed an international reputation not only as a chemist, but as an administrator and a historian. The respect felt for his scholarly ability in many fields was accentuated by the universal affection inspired by his modest and kindly personality. He was indeed a true gentleman, in the oldest and best sense of the word.

Born at York, Pennsylvania, where his ancestors settled several generations ago, on May 23, 1856, Dr. Smith successfully resisted his father's plans for a business career, and resolved to study medicine. He prepared for college at the York County Academy and entered the junior class of Pennsylvania College, Gettysburg, in 1872. Before he graduated in 1874 with the degree of bachelor of science, his work in chemistry had been of such promise that his teacher, Dr. S. P. Sadtler, encouraged him to go to Germany and continue his studies there. Acting on this advice, Dr. Smith worked for two years at Göttingen, where Wöhler was one of his professors, and gained the degree of Ph.D. Returning to the United States in 1876, he became an assistant in analytical chemistry to Professor F. A. Genthe, of the University of Pennsylvania.

At this institution, except for brief intervals at Muhlenberg College, Allentown, Pa., and at Wittenberg College, Springfield, Ohio, Dr. Smith spent the rest of his active career until his retirement in 1920. He became in 1888 professor of analytical chemistry, in 1892 head of the department of chemistry, in 1898 vice-provost and in 1911 provost of the university. During his forty-four years of teaching and administrative work, he gained the title of "the best beloved college professor in America" and impressed his spirit and personality upon more than fifty thousand students.

Honors in abundance came to Dr. Smith for his unselfish labors. Besides more than twenty degrees from different universities, he was awarded the Elliott Cresson medal of the Franklin Institute, the Chandler medal of Columbia University and the Priestley medal of the American Chemical Society. He served thrice as president of the American Chemical Society, in 1895, 1921 and 1922. These distinctions were not accompanied by corresponding material prosperity, for which Dr. Smith cared little. Although he was a public servant on innumerable boards and committees in local and state interests, he consistently declined public honors and advancement, engaging in philanthropy to the limit of his resources, secretly supporting poor students and contributing to many charities. On his retirement he applied to the Carnegie Foundation for a pension, declaring that he was penniless, and of his career as a teacher he said: "That is wonderful but unremunerative work. And one does not grow rich, either, from writing text-books on chemistry."

An indefatigable research worker in the subjects of mineralogy, electrochemistry and analytical chemistry, Dr. Smith published more than two hundred original papers. His investigations upon the rarer metals have been of industrial as well as academic, significance. He wrote, translated and edited a large number of text-books. During his later years he became particularly interested in the early development of chemistry in America, and his historical studies in this field are of



THE HEADQUARTERS OF THE ARNOLD ARBORETUM

notable literary merit as well as of great scientific value.

In 1926 a statue of Edgar Fahs Smith was erected near the Harrison Chemical Laboratory of the University of Pennsylvania. In the hearts of his colleagues, however, he needs no more permanent memorial than that which his own sterling qualities gained for him. At a dinner recently given in his honor at the Chemists' Club in New York City, he was introduced as follows: "Edgar Fahs Smith, gentleman, chemist, great teacher, historian, true philosopher and sincere friend. Few men have so richly deserved at once the esteem in which Dr. Smith's professional achievements are held and the affectionate respect his character and personality have won."

Dr. Smith practically died in harness, since one of his last acts was to attend the spring meeting of the American Chemical Society at St. Louis. On the return journey, he contracted a chill, which developed into pneumonia. He is survived by his wife, Margie A. Gruel, of Gettysburg, whose tender care and companionship brightened his life for nearly fifty years and to whom the deepest sympathy of all his friends is extended in her bereavement.

James Kendall

THE ARNOLD ARBORETUM OF HARVARD UNIVERSITY

The Arnold Arboretum of Harvard University was established in 1872 for the study and cultivation of all the woody plants capable of withstanding the climate of Massachusetts. Its original endowment was one hundred thousand dollars, left for this purpose by James Arnold, a merchant of New Bedford, Massachusetts. For the purpose of carrying out this trust Harvard University set aside 125 acres of land known as the Bussey Farm. In 1873 Charles S. Sargent was appointed director, a position he held until his death on March 22, 1927. By an arrangement with the city of Boston, who maintain the roads as part of the park system, the Arnold Arboretum is assured of its present site for a thousand years and is tax free. It is policed by the city of Boston and is open to the public from sunrise to sunset every day in the year. When Professor Sargent died he had increased the endowment of the Arnold Arboretum to over a million dollars and the area to about 260 acres, wherein are now grow-

AN INTERIOR VIEW

ing more than six thousand five hundred species and varieties of tree, shrub and vine. To commemorate the life work of Professor C. S. Sargent and to still further increase the services of the Arnold Arboretum a Charles Sprague Sargent Memorial Endowment Fund for a million dollars was undertaken and so far more than nine hundred thousand has been collected. On the death of Professor C. S. Sargent, Professor Oakes Ames was appointed supervisor and Mr. E. H. Wilson, who had been assistant director, was made keeper.

Among the changes that have taken place, a new and larger greenhouse and nursery for the Arboretum is being erected on the South Street side of the Arboretum on the rising ground of the Bussey Institution. A new feature of the greenhouse will be a laboratory fully equipped for research in plant pathology and genetics. The greenhouse will be about fifty feet long and will have, also, a workroom for potting, and pits for the growth of woody plants. The nursery, a few feet away, will cover about three acres of land.

Professor Oakes Ames has stated that:

> A most important part of the Arboretum work —hybridization and the study of living conditions and diseases of plants with a view to improving their inherent qualities—has never been attempted before because the necessary facilities were lacking. Up to now its main work has been the assembling of woody plants and trees from all parts of the world, identifying, classifying, propagating them and exchanging them with other arboreta and nurseries, and building up a matchless library and an outstanding herbarium. For lack of funds the Arboretum has thus been limping along on one leg, although limping very efficiently because of Professor Sargent's able direction.

With part of the income from the million dollar endowment fund now being sought, it is proposed to establish two departments of research so that students and dendrologists may take advantage of the wealth of material that has been amassed during the past half century. It is hoped that the economic quality of native trees will be improved, just as scientists have improved flowers and fruits. By cross-fertilization of different varieties and species of forest trees it is expected that great improvement in the economic value of woods will result. Professor Ames explained:

> We want to make the Arboretum a world center not only of systematic dendrology, but of dendrology as a whole. The proximity of the new greenhouse to the Bussey Institution will make possible a closer cooperation than has been possible heretofore. The Arnold Arboretum is the only one in the United States which is connected with a university and can draw upon the specialists in its faculty for scientific help.
>
> Already we have in view for these courses two men in the first rank in their fields, although no definite arrangements have been made to secure their services. If we succeed in getting the right man for the course in plant pathology this work will begin about July 1. Dr. East, at the Bussey Institution, will supervise the work on genetics. We shall also add to the staff another systematic botanist whose field will cover the woody plants of tropical America.
>
> A tentative plan offers to advanced research students at the Arboretum an opportunity to carry on special work in dendrological directions. Inducements will be offered to persuade able men to take their doctor's degree in dendrology at the Arboretum, as there is great need for more experts in this field who are interested in developing quicker-growing trees and improved woods better suited to the manufacturing needs of the future.
>
> The assembling of rare species and varieties of plants will be continued, of course, so that the Arboretum may remain in the forefront of gardens of its type.
>
> The Arboretum is looking eagerly toward Spanish Honduras, at present, as very little is known of its plant life because it is a difficult country for the white man to explore. It is hoped to send an expedition there in the near future, as anything found there would be exceedingly valuable from a botanical point of view.

THE SCIENTIFIC MONTHLY

AUGUST, 1928

THE WASTING HERITAGE OF THE NATION

By HUGH HAMMOND BENNETT

BUREAU OF CHEMISTRY AND SOILS, U. S. DEPARTMENT OF AGRICULTURE

I

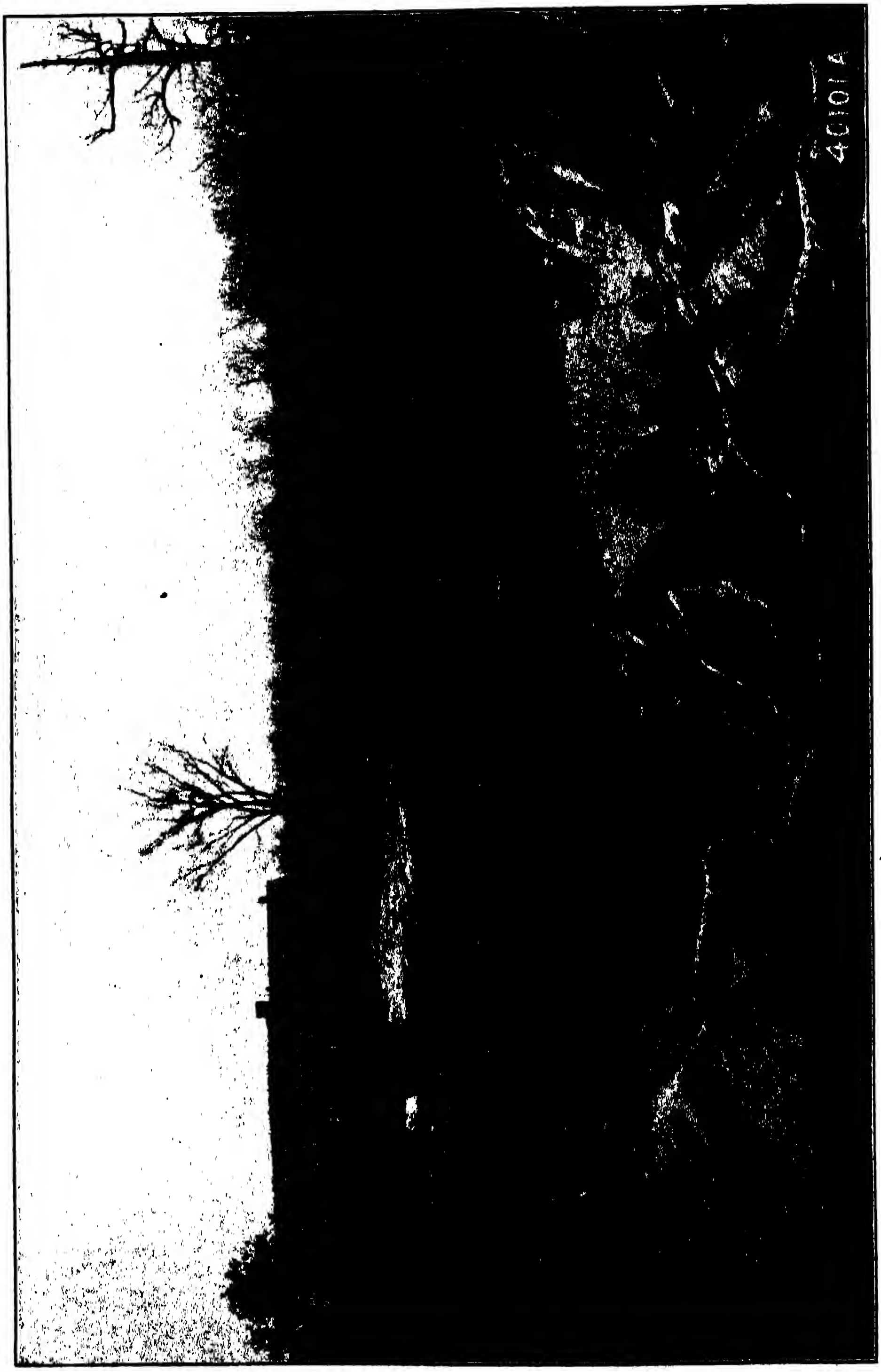
SOIL wastage by erosion is the most serious problem relating to land utilization in this country. It is the direct cause of the distressing financial condition of thousands of farmers struggling with lands enfeebled or worn out by rainwash. Crop surpluses, with their depressing effect upon prices of farm products, come and go; but land impairment by erosion is a costly evil that stays. Indeed, it is a problem which with the prevailing absence of national concern about it, is growing steadily worse. It affects nearly all sloping areas over most of the uplands of the nation, and there is but little upland which is without slope. Even the areas that seem flat to the eye usually have sufficient slope for rain-water to flow off the fields and pastures. Wherever this happens there is some washing away of the soil. The removal is slower on the smoother lands, and the effect is less serious on some lands having peculiar resistance to the process. With increasing slope the transporting and eroding capacity of running water is greatly enlarged, since the load flowing water is capable of carrying, and also the abrasive effect, increases enormously with the velocity.

We sometimes hear farmers and even scientific agriculturists say, "Erosion is not a problem in our locality." In some places it is not a very serious problem, to be sure; but in many other localities where it is believed not to be operative at all, much damage is actually being done. In time the cumulative effect of soilwash becomes painfully apparent, as spots of unproductive clay and exposed bedrock and as fields from whose surface the entire soil has been stripped off. The hideous gullies that mar the landscape of so many localities represent the more advanced and spectacular work of erosion; and, although something in excess of thirteen million acres of formerly cultivated land in this country have been permanently ruined for farming purposes by gullying, this form of devastation constitutes but a small fraction of the wastage.

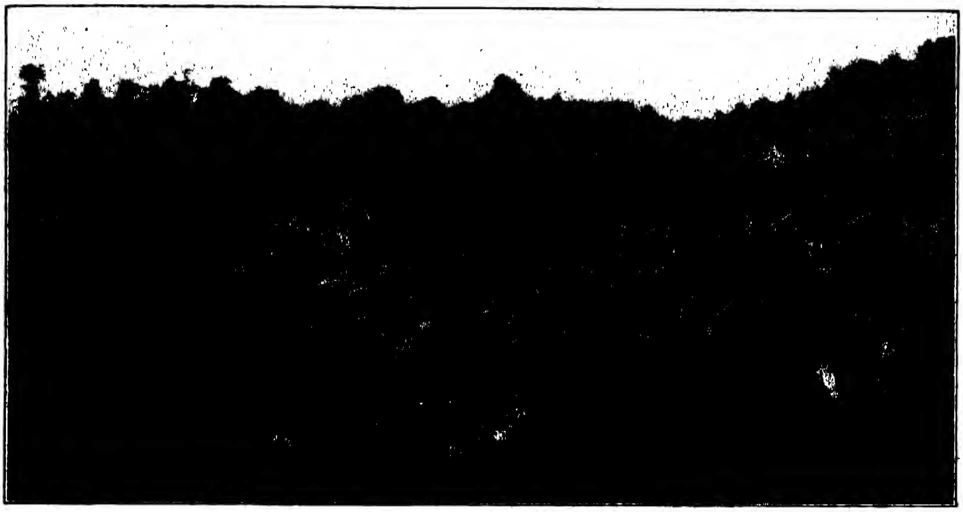
It is sheet erosion that is doing most damage to our farm lands and overgrazed pastures. By this process the surface of the ground is gradually planed down more or less equally at all points. Every heavy rain and even the showers of springtime strip from the cultivated land sheets of soil matter, and this from the surface, the richest part of the fields. If, after a fall of rain, one looks, one sees wherever there is cultivated and over-grazed land water flowing across the slopes and down the rills and brooks, not clear but discolored or turbid with soil material gathered from the countryside. This coloring matter represents so much soil and soil fertility gone for eternity, so far as the areas whence came the material are concerned.

II

Abnormal soil washing, with the helpful assistance of man, is doing more dam-



GULLY NEAR FARM HOUSE, PANOLA COUNTY, MISSISSIPPI



LAND DESTROYED FOR CROP USE BY UNRESTRAINED EROSION
NEAR CONTACT OF THE PIEDMONT AND BLUE RIDGE MOUNTAINS.

age to the agricultural lands of the nation than all other processes, both natural and artificial, combined. The writer is conscious of the fact that this statement covers considerable territory, being fully cognizant of the large amounts of plant food lost from the soil by the leaching of rain-water and by the crops removed, and that in past time volcanoes have poured over the earth sheets of molten lava; that earthquakes have caused mountainsides to crack and go down into valleys as vast, destructive landslides; that coal strippers and gold diggers have churned up many acres in search for hidden wealth; and that many other activities of man have despoiled the ground surface. Nevertheless, the damage done by rainwash greatly exceeds the combined effects of all these other activities of both man and nature. More than eight tenths of the area of the United States is underlain by sedimentary deposits; that is, rocks and unconsolidated strata composed of material that was washed, largely or entirely, from older land areas, some of which have been completely effaced from the earth. These water-formed beds are thousands of feet in thickness. It is not uncommon to drill into them more than four thousand feet for oil. Through the eons of geological periods the rocks of ages have decayed to give the material of our soils, and from the very beginning rainwater impinging against these detrital products have torn them asunder and distributed them to the seas to form new land areas of coastal marsh and submerged continental shelfs. The gashes this instrument has cut are utterly beyond calculation. Some parts of the Blue Ridge Mountains of the Appalachian System have been hewn down through thirty thousand feet of decayed rock and eroded soil, or ten times their present height.

Long before the ancients began to build temples to the sun, Mother Nature was busy fashioning such superb examples of rock architecture as the Grand Canyon of the Colorado, Victoria Falls and the Magotes of Western Cuba. Man can not hope to match these structures of destruction. Nor should there be any desire to match them, for they are the products of tearing-down processes. Erosional work of this kind represents the accumulated effect of slow geologic processes that always have been active

THE WORK OF A NORTH CAROLINA FLOOD

IN THE BLUE RIDGE REGION: FINE SOIL STRIPPED OFF DOWN TO THE BOWLDERS.

and always will be, inexorably abrading rock and soil in striving to level down the earth's surface.

Nevertheless, man has entered very actively upon the task of assisting nature with the work of land destruction. By cultivating unprotected and excessively steep slopes, hundreds of thousands of square miles have been brought to complete ruin throughout the world, and far greater areas have been seriously impaired by unrestrained rainwash. Solid rock and sterile, gullied slopes frown down from stripped uplands over vast areas of China and Asia Minor. Unwise treatment of sloping land by the farmers of the past has so restricted the area of China's arable land that hordes of highlanders have been driven into the valleys for sustenance, or forced to husband their remaining soil upon terraces built like scaffolds along the sides of hills and mountains. With the best possible utilization of the remaining soil, famines are continually recurring upon that disturbed part of the earth's surface. In some parts of the world wastage of fertility by erosion has caused the downfall of nations, and even the destruction of civilizations.

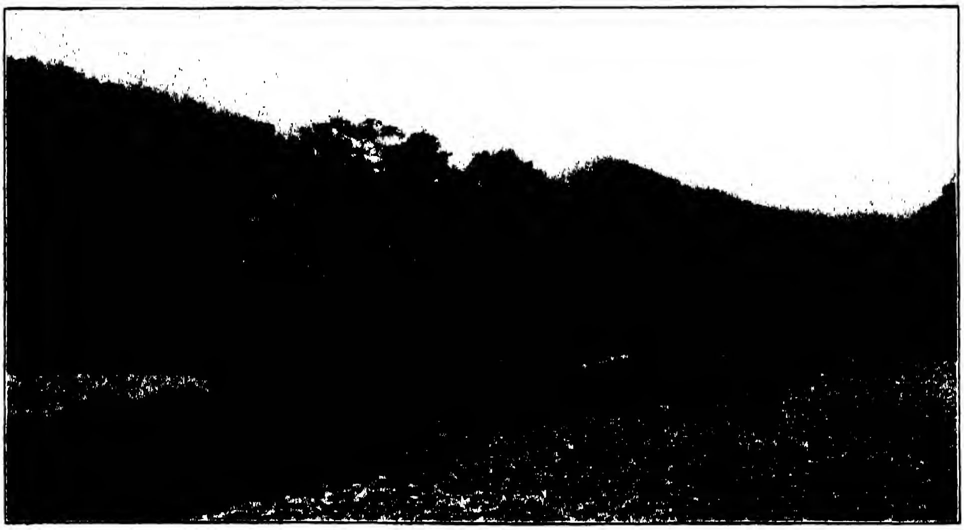
III

Youthful America is not guiltless of unwise use of the land upon a large scale. Steep slopes and land that washes much too readily have been used for crops without provision for checking rainwash; indeed, they often have been used in such manner as to encourage and accentuate the wastage. Even grazing lands have been sorely impoverished or destroyed in many parts of the west and in some parts of the east. The impoverishment and devastation, most of which could have been prevented, have gone on in nearly all parts of the country, from the Gulf to the Canadian border states, from New Jersey to California. At the present moment the rate of land depreciation from this cause is greater than ever, and, unless very largely increased efforts are made to check the inroads, it can safely be asserted that we are but upon the threshold of this process of land despoliation.

HIGH PIEDMONT PLATEAU

WHERE THE SOIL IS ERODING SO RAPIDLY TREES ARE HAVING DIFFICULTY ESTABLISHING THEMSELVES. THE LAND WAS FORMERLY CULTIVATED.

If we continue to twiddle thumbs and warn our brothers not to be stampeded by the wailing of those apostles and prophets, who, brimming with enthusiasm or pessimism, recurrently wave red flags of fear and point to direful dangers lurking around the corner, then we of to-day are going to be the recipients of much tongue-lashing by our children a few generations hence. Already such blasphemy is to be heard in many parts of the country. Down in the southern Piedmont, for example, where ninety thousand acres of formerly good farm land have been destroyed in a single county, serious-minded citizens speak vehemently of the shameful land practices of the farmers of one, two or three generations ago, not to mention some of those who, still operating, call themselves farmers instead of soil miners. The ninety thousand acres that stare them in the face, a grinning skeleton of land that could have been saved, is not a guess. The area was studied in detail by experienced soil scientists and its outlines carefully plotted on a government map. It was classed as gullied land having no further agricultural value, save for an occasional strip temporarily left between expanding gullies. Bedrock has been exposed in a thousand places. In brief, this area has been so completely devastated over most of its extent, it can not be reclaimed to cultivation until centuries of rock decay have restored the soil, and it has only moderate value for tree growth.



SHOWING EROSIONAL DEBRIS

CAUGHT BY A LOG OBSTRUCTION IN A STREAM OF WESTERN NORTH CAROLINA.

IV

Too few are concerned about land destruction of this nature, even when it is pointed out that this wasted Piedmont area is but one of a vast number of similarly eroded areas throughout the country, many equally bad and others worse. If a foreign nation should invade this country and destroy ninety thousand acres of land, who doubts the nation would hasten to spend twenty billion dollars to redress the wrong or as many billions as might be necessary. That rainwater was the agency of destruction, too many people look upon the situation with indifferent complacency, regarding it as regrettable, perhaps, but as an unavoidable natural eventuality.

It can be avoided. Not with this par-

CULTIVATION ON THE BLUE RIDGE

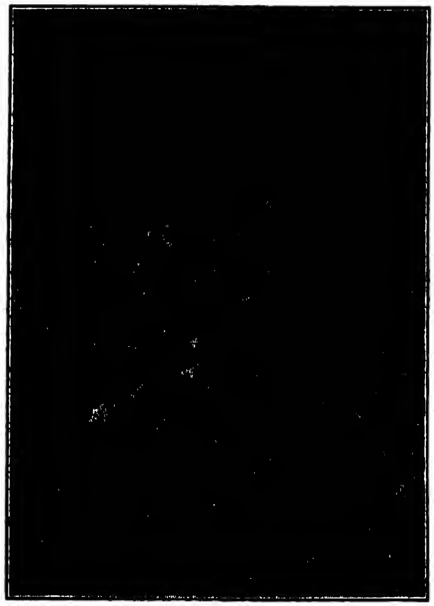
IT WAS A CRIMINAL ACT TO ATTEMPT CULTIVATION ON THIS STEEP BLUE RIDGE SLOPE, EVEN IF THERE IS NO MAN-MADE LAW AGAINST THE FOLLY.

ticular tract; no, that is permanently lost. But this kind of wastage can be largely prevented, if we will. Other areas, not yet destroyed, can be saved by terracing and other means. This has been proved abundantly through the southeastern states, where thousands of energetic farmers have kept their sloping fields in good state of productivity for more than two generations by the practice of hillside terracing, a system of contour embankments.

In another county, of the coastal plain region, seventy thousand acres of former rich soil have been gullied beyond repair. In one place where a schoolhouse stood forty years ago, gullies more than a hundred feet deep now finger through hundreds of acres of land, all formerly good soil, whose reclamation would baffle human ingenuity.

VIEWING THE REMNANTS OF A WASTED FARMSTEAD IN THE PIEDMONT

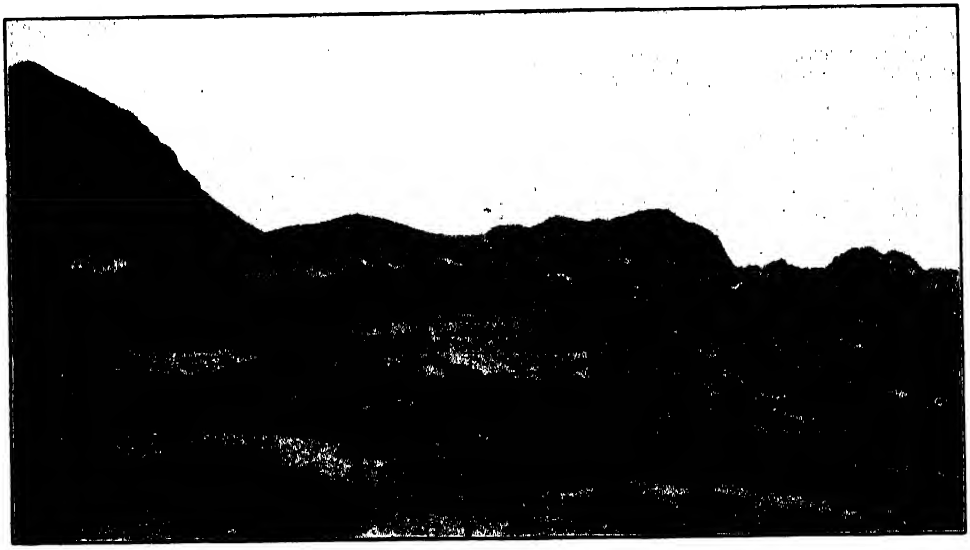
In the great region of loessial soils, the Brown Loam Belt that follows along the east side of the Mississippi River from Baton Rouge, Louisiana, northward across Mississippi, Tennessee and south-



FINE GRAIN SOIL IN NORTHEAST KANSAS

IN THE FALL OF 1927 A SINGLE RAINY PERIOD TOOK OFF MORE THAN FORTY TONS OF SOIL PER ACRE FROM THIS LAND. THE YOUNG GRAIN ALSO WAS LARGELY WASHED OUT.

western Kentucky, and onward far up the Missouri and its tributaries, county after county includes ten, twenty or thirty thousand acres which have been destroyed by gullying and sheet erosion. In some of the more southerly counties of this region agriculture has been largely driven out of the uplands, and many tracts of rich alluvial soil have been buried beneath a blanket of comparatively inert sand deposited by flood



CHANNEL-TRENCH EROSION

ABOUT TO DESTROY A GOOD GRAZING VALLEY IN THE ARID SOUTHWEST.

water. Stream channels have been choked with erosion-débris, and overflows have become so exceedingly common that large tracts of highly productive alluvium, formerly tilled, are now rated as swamp land having little value for any purpose. Some streams, formerly navigable, have been so choked with sand and mud they can no longer be plied by boats.

FIELD NEAR RALEIGH, N. C.

THIS EXCELLENT FIELD, FORMERLY BADLY WASHED AND UNPRODUCTIVE, HAS BEEN RECLAIMED BY TERRACING.

SHEET EROSION

RICH TOPSOIL REMOVED FROM ONE PART OF THE FIELD TO SMOTHER THE CROPS IN ANOTHER PART. THIS FIELD IS ON FERTILE IOWA BLACK LAND.

Dr. E. N. Lowe, state geologist of Mississippi, has this to say of the situation:

In many of our northern uplands, washing of the soil is progressing so rapidly, without let or hindrance over large areas, that some necessary measures must be adopted soon to arrest the process, otherwise vast areas of formerly agricultural lands will become hopeless wastes. Large areas in at least a dozen upland counties of north-central Mississippi have already reached such a condition of soil depletion that they are now hardly suitable for any kind of agriculture, and their taxable values are reduced accordingly. . . .

The erosion of these uplands has resulted not only in enormous losses of valuable agricultural soils, but also in concomitant stream-filling throughout these areas. Volumes of silt and sand after every heavy shower are poured into the streams from every furrow, gully and rill that trenches the hillsides, resulting in filling of their channels. The obliteration of their channels causes overflow of the streams after any considerable rain, with deposition of sand over valuable bottom lands, often doing irreparable damage. . . .

For years rapid and destructive filling has affected the Coldwater. Forty years ago boats of large size came up the river to Coldwater to load cotton. Now no kind of boat can come up Coldwater River, so choked is it with sandbars. Thirty years ago a large fertile cotton plantation existed on the river flat just below Coldwater; for years past it has been abandoned, and is grown up in willow thickets, as useless land, all because the filling of the river channel has caused constant overflows on this land, covering it with sand beds.

CROPS SMOTHERED BY TOPSOIL

WASHED FROM ADJACENT SLOPES. SHEET EROSION IN IOWA, WHERE NOTHING IS BEING DONE TO CONTROL THE WASTE.

EROSION IN THE TRANS-PECOS COUNTRY OF TEXAS
THIS STARTED IN A PLACE WHERE CATTLE REMOVED ALL THE GRASS.

In the black belt of Central Texas, one of the greatest cotton-producing regions of the world, white areas representing the basal chalk and marl beds dot the landscape of the rolling sections. These are the product of erosion. They consist of non-arable land that has taken the place of some of the most productive cotton soil known anywhere. In one county 13.5 per cent. of the entire land area was classed as eroded land whose productive value has been very seriously impaired or practically destroyed.

V

Let's not get the notion that the washing away of valuable farm land is restricted to the southern states.

The government soil experts who recently completed a land survey of a

PROTECTING THE BOTTOM LANDS IN KANSAS
THE MAN IN THE BACKGROUND IS STANDING ON A TERRACE 8 FEET ABOVE THE MAN IN THE FOREGROUND, WHO STANDS ON MISSOURI RIVER BOTTOM LAND. THE LATTER IS EXTREMELY PRODUCTIVE SOIL OF THE WABASH SILTY CLAY LOAM VARIETY. THE TERRACE IS THE RESULT OF A DYKE BUILT ABOUT 10 YEARS AGO TO INTERCEPT THE EROSIONAL DÉBRIS SWEEPING DOWN FROM THE NEAR-BY UPLANDS. THE FARMER OBJECTED TO HIS RICH BLACK BOTTOMS BEING COVERED BY LESS PRODUCTIVE WASH FROM THE HILLS. THIS FILLING-IN TOOK PLACE OVER 40 ACRES AT THE RATE OF 1,200 TONS PER ACRE PER YEAR. IT ILLUSTRATES HOW VERY RAPIDLY SOIL MATERIAL IS BEING REMOVED BY RAINWASH, AND, ALSO, THAT NOT ALL OF IT PROCEEDS IMMEDIATELY TO TIDE-WATER.
(PHOTOGRAPH TAKEN ON OCTOBER 17, 1927, NORTHERN DONIPHAN COUNTY, KANSAS.)

REPRODUCTION OF BLACK LOCUST
IN THE VALLEY OF VIRGINIA: A GOOD CROP FOR WASHING HILLSIDES.

county in northeastern Kansas found that an average of at least six inches of soil had been removed from the uplands of the county, where the predominant soils are silt loams, highly productive types, as valuable for the growing of corn and wheat probably as any upland known to man.

Nearly all tilled slopes of this county were found to have suffered, some much more severely than others. In one part of this area that was examined by the writer in the fall of 1927, a tract of original timber was seen, which had from one to two feet of extraordinary rich silt loam soil overlying clay. This was so abundantly supplied with dark humus and so mellow and permeable it was easy to dig down with the bare hand to the depth of the subsoil. Outside the timber on the same degree of slope the same soil in most places had lost all the surface material down to the clay, and in many places six inches or more of the subsoil itself had washed away. Indeed, patches were found where both soil and subsoil had departed, leaving bedrock exposed. One valley was found by actual survey to have lost from eight to forty inches of soil over 86 per cent. of its upland area since clearing forty years ago. In apple orchards on these wasted lands the trees were making no growth, or were dying, as the result of excessive loss of moisture on the sun-baked clay in times of drought.

Near the Kansas-Nebraska line an apple orchard was seen in the bottom of a beautiful valley where the trunks of the trees had been completely buried by silt washed down from the adjacent hill-sides and ridge crests. The raised surface of the ground stood among the branches of the trees, five feet above the original level of the orchard. The owner said the trees had shown no evidence of damage by the deposition. "But the trees were doing nicely before this washed-in material was deposited about them; they needed no more soil. The soil is needed very badly up there on the thin slopes where it came from."

PIEDMONT GULLY IN ANSON COUNTY, N. C.

ALMOST FILLED BY EROSION-ARRESTING PINES (ON FARM OF DR. J. H. BENNETT, WEST OF WADESBORO). THIS IS AN EXAMPLE OF WHAT SHOULD BE DONE ON MANY THOUSANDS OF ACRES OF LAND IN THE SOUTHERN STATES.

Close by this orchard a gully is advancing at a minimum rate of one hundred and fifty feet a year. This is seventy-five feet deep, three hundred feet wide in places and nearly three-fourths of a mile long. It is destined to destroy all the farm land in this fertile valley, and its diverging trenches undoubtedly will cut to pieces the adjacent highlands.

Many valleys in the youthful agricultural country along the Missouri and its tributaries have undergone the same or similar vicissitudes. As a result, fields, and in some instances entire farms, are being abandoned. Sheet erosion is gradually thinning down the gentler slopes far back from the river. In many places twelve or fifteen miles from the Missouri, numerous wheat and alfalfa fields seeded in the fall of 1927 were severely damaged during a single period of autumn rains. Each depression made by the seed drills was converted into a rillway or small gully, while the wheel tracks of the seeder rapidly grew into ugly ditches. Most of the young plants were washed out of the ground and forty tons of soil an acre were carried off the steeper slopes. The only instance observed in several Missouri and Kansas counties of this region where a farmer had done anything to check the wastage was that of a series of wheat-straw stacks placed in a depression at the base of converging slopes. One of these stacks had caught and held four hundred and thirty tons of soil which had been washed down from the near-by slopes during the rainy period referred to. That sort of thing, however, can scarcely be considered as a real effort at soil conservation; for the place to hold the soil is in the fields and not in the valleys after it has left the fields.

There are no soil-saving terraces in this region, as a rule. The farmers generally do not even know what they are. Practically nothing is being done to con-

VIRGIN TIMBER IN NORTHEAST KANSAS

THE SOIL HERE IS TWELVE TO TWENTY-FOUR INCHES DEEP OVER CLAY—MELLOW, RICH IN HUMUS AND OF SILT LOAM TEXTURE. OUTSIDE IN THE WEED PATCHES ALL THE TOP-SOIL HAS BEEN WASHED OFF DOWN TO THE CLAY, AND THIS ON THE SAME SOIL AND SLOPE AS THAT COVERED BY THE FOREST.

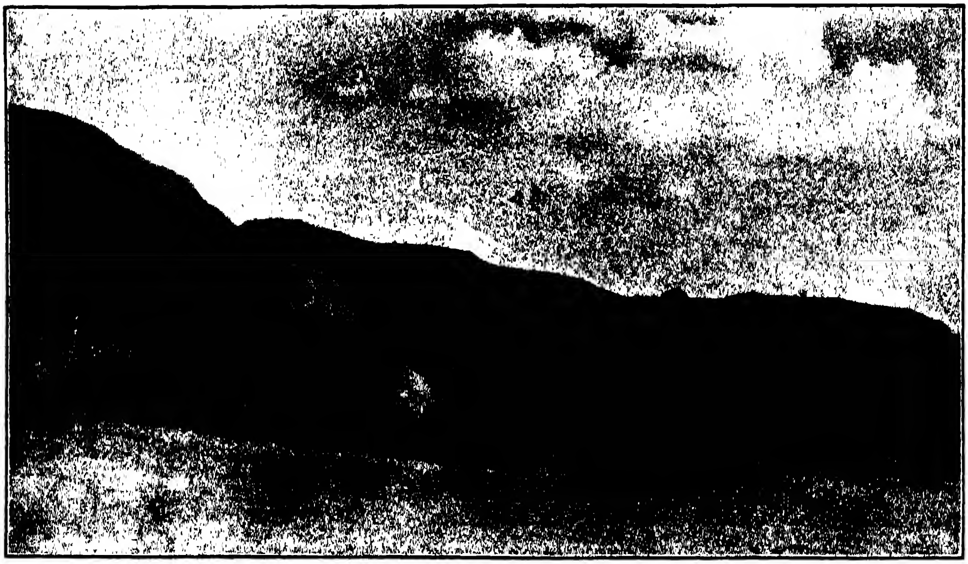
THE EFFECT OF GULLYING

FORMER SPLENDID VALLEY GRAZING LAND OF FAR-WEST TEXAS BEING DESTROYED BY GULLYING THAT HAD ITS BEGINNING IN A ROADWAY.

serve the soil; whereas a very great deal is being done to hasten its loss, such as plowing corn rows up-and-down the slopes, thus forming gutter-like "middles" to serve as ditches for concentration and increased scouring effect of rainwater. Where the rows accidentally follow the contour it is a common practice in springtime to plow furrows down the slopes in order to lead the water out

AN EXAMPLE OF COAST EROSION

TWO WEEKS OF SOUTHWEST WINDS CUT BACK THE SHORE-LINE TWENTY FEET ALONG THIS PART OF THE GULF COAST, AND IN DOING SO, DESTROYED CONSIDERABLE FINE TIMBER.



ARID SOUTHWEST HILLS

WHICH ONCE AFFORDED GOOD GRAZING FOR GOATS. OVER-GRAZING AND EROSION HAVE COMPLETELY DENUDED THEM OF VEGETATION. OVER LARGE AREAS NOT A TREE, NOT A BUSH, NOT ONE SPRIG OF GRASS IS TO BE SEEN. THE LAND IS SIMPLY A SKELETON OF FORMER CONDITIONS. IT IS A DESTROYED PART OF THE EARTH, AS GHASTLY AND USELESS AS A SUN-BAKED SKELETON.

of the inter-row depressions. Almost invariably these furrows grow into deep gullies that divide, capture and render useless for cultivation field after field.

This neglect of the land to the unceasing impoverishing effects of erosion is the rule, not the exception, throughout the entire central and upper Mississippi Basin. It is not restricted to the Missouri River area by any means.

VI

One might reasonably suppose that erosion is of negligible importance in the dry regions of the west. Such is not the case, for many localities, at least. Because of certain soil peculiarities, such as the common tendency for the soils of the drier regions to crack or crumble into a loose, fluffy condition on drying, erosion is exceedingly severe in many parts of the west, even in desert areas.

In the cattle country of west Texas and central New Mexico, numerous places were observed recently, where deep rich valley soil, representing the accumulation of ages, had been washed out largely or wholly, leaving behind an absolute waste. The washing that causes the destruction or extreme impairment of these valuable grazing lands usually has its beginning in those places where the vegetation has been removed and the ground surface broken, as in cattle trails and bedding grounds, roadways, diversion ditches and prairie-dog towns. In one valley area of the Davis Mountain region of west Texas a thousand acres of former good grazing land was found to have been almost completely destroyed as the result of washing started in a prairie-dog town, where the vegetation had been eaten and the ground punctured with holes.

Large grazing areas of the west have suffered seriously from erosion induced by overstocking. In regard to this growing menace to the ranges, W. R. Chapline, the range expert of the Forest Service, says:

PLANTING RUBBER TREES IN SUMATRA

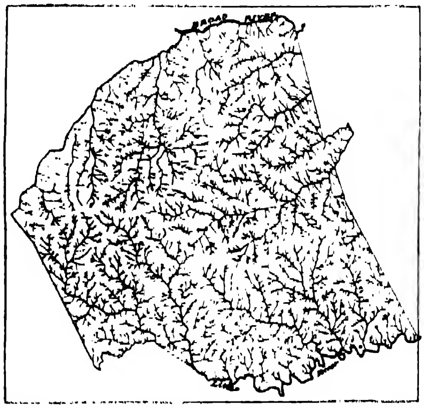
ON EXCAVATED TERRACES. SOME OF THE RUBBER PLANTATIONS OF THE EAST INDIES TAKE BETTER CARE OF THEIR LAND THAN MOST OF THE FARMERS OF THE UNITED STATES.

As early as 1890 range grazing lands were stocked to their capacity, while some were already overstocked. The continued overstocking over numerous areas reduced the carrying capacity, both by cutting down the quantity of forage produced and by increasing erosion of the productive surface soil. Reduction in grazing capacity necessitated decreasing the numbers of livestock, with resulting excessive per head investments in lands and improvements and uneconomic production. Furthermore, the erosion has carried millions of tons of silt from the ranges into irrigation and other reservoirs; the floods have ruined many farms by a blanket of sand and gravel, and have destroyed roads and other works. The financial loss to the farmer has been as great as that to the livestock producer. The greatest loss has doubtless been the lowered productivity of the soil on the ranges and the difficulty of re-establishing a satisfactory protective covering.

STAND OF SHORTLEAF PINE

ON ABANDONED FIELD IN EAST TEXAS. THIS IS THE BEST CROP FOR SOME MILLIONS OF ACRES OF EROSIVE LAND IN THE SOUTH.

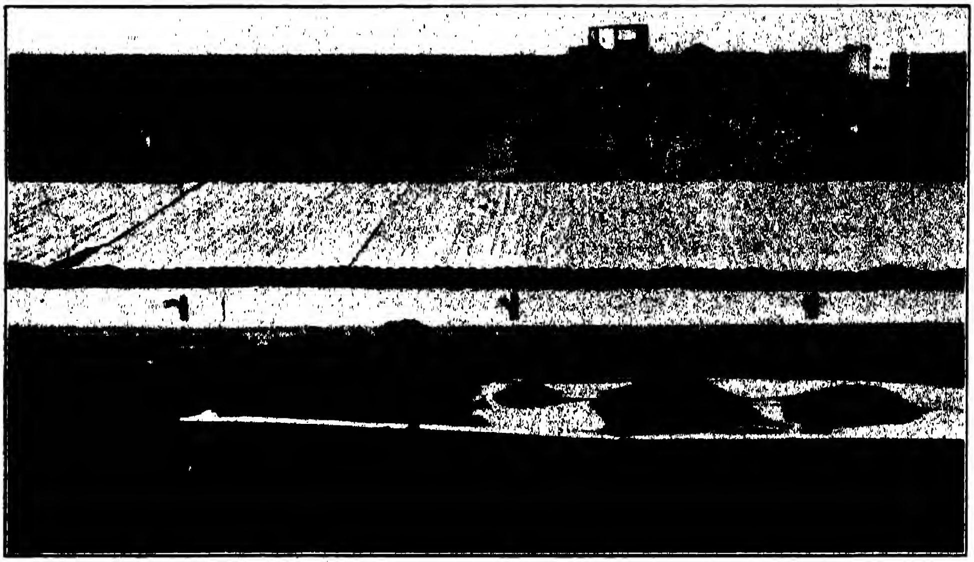
Recently a layer of infertile sandy material swept out from a burned-over hillside in the southwestern United States was deposited over an orange grove of great value. The trees quickly showed distressing injury, some of them dying. It became necessary to rake the infertile detritus back from the base of



THOROUGH DISSECTION OF A PIEDMONT COUNTY BY DRAINAGE LINES

INNUMERABLE TRIBUTARIES TO THE STREAMS SHOWN EXIST IN MANY PARTS OF THIS COUNTY IN THE FORM OF EROSION GULLIES.

the trees, wherever the deposit was less than a foot thick, and to haul it out of the grove where it was deeper. It is said to have cost a hundred thousand dollars, or twelve hundred dollars per acre, to remedy the distressing situation, which was brought about as the result of a single rainy period. The grove can not stand another such disaster, as the owners see it. And there will be many other farms in many other parts of the nation that will not be able to stand the cost if we do not do a great deal more than we have done in the past to check the evils of erosion. Writing of the



THE EROSIONAL WORK OF ONE RAIN

i.e., WASH-OFF OF SURFACE SOIL MATERIAL FROM VERY MILD SLOPE AT THE SPUR STATION, TEXAS, SHOWN IN PILES ON WHITE CLOTH OF FOREGROUND, LEFT TO RIGHT: FIRST, FROM BARE-GROUND PLOT, WEEDS REMOVED WITHOUT DISTURBING THE SOIL; SECOND, FROM GRASS PLOT; THIRD, FROM GRAIN-SORGHUM PLOT; FOURTH, FROM COTTON PLOT. EROSION ON THIS 2-PER CENT. SLOPE AMOUNTED TO FORTY TONS OF SOIL MATERIAL PER ACRE WITH TWENTY-SEVEN INCHES OF RAINFALL.

wastage, Mr. G. E. Martin, of the Oklahoma extension service, says: "The loss constitutes a most serious drain upon the agricultural industry. It is very unlikely that any other industry could suffer such severe losses and survive."

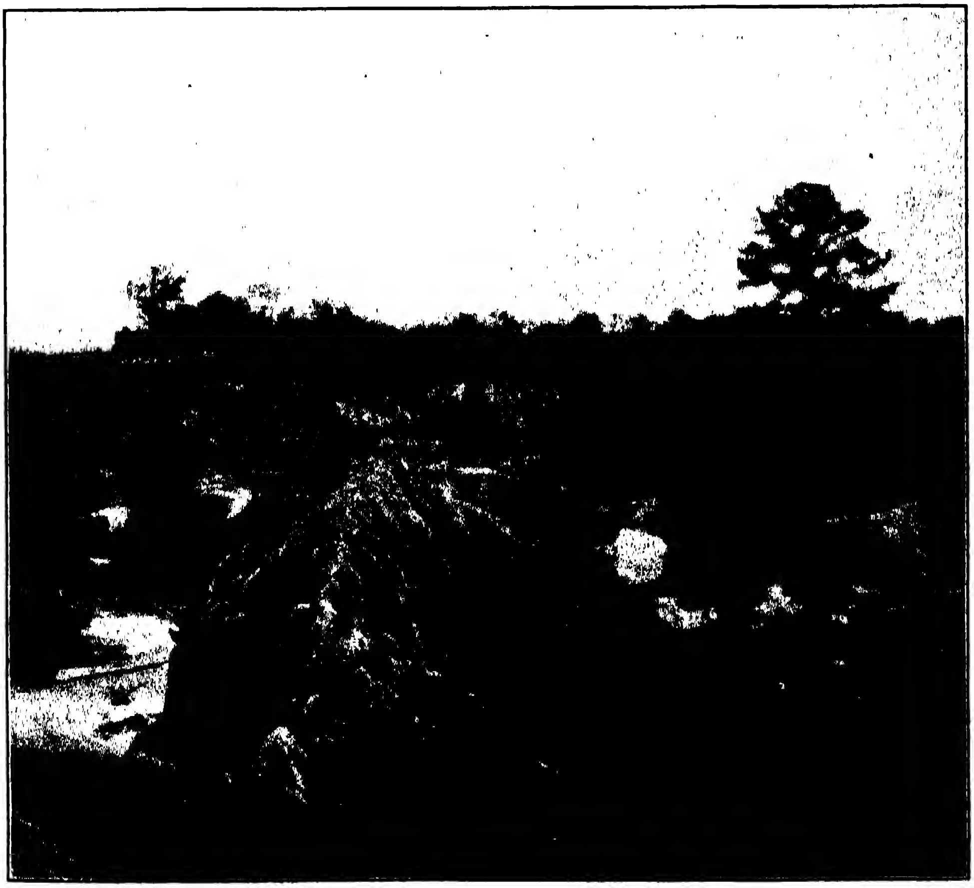
Putting the matter in more tangible terms, in pounds of plant food wasted and in values with the dollar mark prefix, it is found that the value of the plant food contained in the soil washed out of the fields and pastures of the

SOIL-SAVING FIELD TERRACES

IN THE PIEDMONT OF NORTH CAROLINA. ON SOME SOILS THESE SOIL CONSERVATION EMBANKMENTS CAN BE CULTIVATED OVER ABOUT AS WELL AS ANY OTHER PART OF THE FIELD.

United States every year, chiefly from the former, exceeds two billion dollars, on the basis of chemical analyses of the soils of the country, and the value of the principal constituents (phosphorus, nitrogen and potassium) carried in the cheapest forms of commercial fertilizers. Of this sum there is evidence that at least two hundred million dollars represents a tangible, annual loss to the farmers of the country; while a considerable part of the remainder is a loss to posterity, since the marshes it goes to build at the mouths of rivers can scarcely be used for some geological eons to come, and the alluvial lands covered need no additional material.

The plant nutrients contained in this wastage exceeds one hundred and twenty-six billion pounds. In other



GULLIES IN THE "BROWN LOAM" COUNTRY

IN SOME COUNTIES IN THE EXTENSIVE AND IMPORTANT SOIL REGION OF THE "BROWN LOAM" (LOESS SOIL) COUNTRY, THAT EXTENDS FAR UP THE MISSISSIPPI-MISSOURI RIVER SYSTEM, AGRICULTURE HAS BEEN LARGELY DRIVEN OUT OF THE UPLANDS BY DISASTROUS GULLYING. THE GULLIES HAVE RIPPED TO PIECES VAST AREAS OF THESE PRODUCTIVE SOILS, WHICH COULD HAVE BEEN SAVED BY TERRACING THE GENTLER SLOPES AND LEAVING TIMBER ON THE STEEPER ONES. THIS PECULIAR TYPE OF EROSION IS THE RADIAL-EXTENSION TYPE, WHICH EXTENDS EQUALLY IN ALL DIRECTIONS, COMPLETELY DESTROYING THE SOIL AND LEAVING INFERTILE CLAY THAT HAS LITTLE VALUE EVEN FOR TREES.

NORFOLK FINE SANDY LOAM SOIL

NEAR THE GULF OF MEXICO. SHOWING HOW SANDY SUBSOIL MATERIAL FLOWS OUT FROM BENEATH THE HEAVIER TOP-SOIL IN DITCHES.

words, the annual bathing bill of our agricultural lands in terms of plant food exceeds the net loss in the crops taken off by more than twenty-one times.

These figures are derived from minimum estimates of soil wastage, based upon the amount of suspended matter delivered by the rivers to tidewater each year, plus a small part of the soil material washed off sloping areas and temporarily stranded en route to the sea. It is known from analysis of river waters that a minimum of five hundred and thirteen million tons of suspended matter and of two hundred and seventy million tons of dissolved matter are yearly transported from continental United States to the oceans. The Mississippi alone takes care of four hundred and twenty-eight million tons of this traffic, in solids alone.

To those familiar with field conditions these estimates will be recognized as being absurdly small; but this point need not be discussed here.

VIII

By catching and measuring the runoff and washoff from a moderate slope, it was found at the Missouri Experiment

GRENADA SOIL OF NORTHEASTERN MISSISSIPPI

RUINED BY WASHING. THE TOP-SOIL GRADUALLY WASHES OFF DOWN TO THE COMPACT WHITE LAYER, THEN RAPID LATERAL WASHING TAKES PLACE, AND FINALLY THE COMPACT MATERIAL IS CUT THROUGH TO INFERTILE CLAY THAT BAKES ALMOST LIKE ASPHALT.

Station that for an average of six years forty-one tons of soil material were washed annually from one acre of land plowed four inches deep; and that 68 per cent. of the rainfall, amounting approximately to thirty-six inches per annum, was absorbed. From an area of the same soil and slope, covered with blue grass, a little less than .3 of a ton of solid matter was removed each year; whereas 88 per cent. of the rainfall was retained. In other words, grass land held back one hundred and thirty-seven times as much soil as the bare area and about 29 per cent. more of the rainwater that fell upon the ground. This rate of erosion would cause the removal of a seven-inch layer of soil from land of this kind, tilled four inches deep, in twenty-four years; whereas the removal of the same thickness from areas under grass would require 3,547 years.

At Spur, in subhumid western Texas, experiments conducted for the purpose of determining the possibilities of storing moisture in the subsoil for summer crop use revealed the astounding fact that forty-one tons of soil matter were removed from one acre by one year's precipitation of twenty-seven inches, and this on ground of only two per cent. slope. A slope no steeper than this is not far removed from level ground, so far as the eye is capable of detecting. Of the rainfall, ground covered with buffalo grass retained 84 per cent., while fallow ground retained only 55 per cent. As the result of terracing the fields, much of the rainfall was stored in the subsoil, and the yield of cotton was considerably increased as a result.

ERODED HILLSIDES

IN DONIPHAN COUNTY, KANSAS, NORTHWEST OF TROY. ALFALFA, SEEDED LAST YEAR (1927), ON THE DARK PATCHES OF MIDDLE-GROUND, AND GRASS ON THE ASSOCIATED LIGHT PATCHES. THE FORMER IS SUCCEEDING FAIRLY WELL WHERE FROM FIVE TO SEVEN INCHES OF THE ORIGINAL SILT LOAM COVERING STILL REMAINS, BUT GRASS HAS DRIVEN OUT THE ALFALFA ON THOSE AREAS WHERE ALL OR NEARLY ALL THE TOP-SOIL HAS WASHED AWAY DOWN TO THE SILTY CLAY LOAM SUBSOIL (KNOX SILTY CLAY LOAM).

The highly valuable loessial or wind-deposited soils of the Mississippi Valley if neglected, melt away with rain, almost like sugar, forming broad and deep gullies that invade the countryside with far greater desolation than that wrought by shell-fire, trench or mine upon the fields of France. The combined extent of land destruction during the World War was small in comparison with the evil work that has been

done by soil erosion in single localities in many parts of the United States.

IX

When the mellow topsoil is gone, with its valuable humus and nitrogen, that which takes its place usually consists of raw subsoil material, often stiff clay. This is less productive, less permeable to plant roots, less absorptive of rainfall and less retentive of that which is absorbed. The exposed raw subsoil, now called upon to function as soil, must in countless instances be improved for plant growth by incorporating with it vegetable matter and by loosening the compact material with increased tillage to allow ingress of air, that agent which with its supply of oxygen is so necessary for the conditioning of soil. Often largely increased amounts of fertilizer are required for satisfactory yields, and lime is needed to correct acidity or otherwise to improve the soil. All these things take time and work and money.

The writer owns land, where, as a boy, he hoed and plowed cotton on deep, mellow loam, from which fields every particle of the topsoil has been washed off down to the clay subsoil, in spite of all that has been done to save the land. To produce as much cotton per acre as these fields formerly gave, it now takes from six to eight hundred pounds of fertilizer per acre, as against two to three hundred pounds before the soil left on its journey to the sea. And this has happened upon neighboring farms, not merely in an occasional field, but in most of the fields. It has also happened in neighboring counties and in neighboring states.

NATIVE AGRICULTURE, PHILIPPINE ISLANDS
EVERY VESTIGE OF USABLE LAND EMPLOYED FOR GROWING RICE.

X

So long as rain falls upon the earth there is going to be soil erosion. The

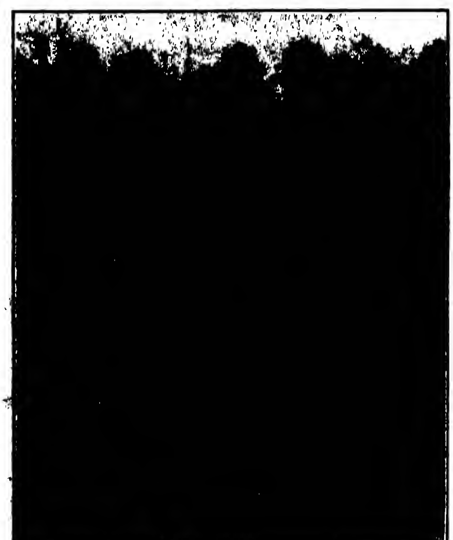
DEEP GULLY HEAD-ON EXTENSION TYPE OF EROSION

GULLIES OF THIS KIND ADVANCE RAPIDLY BY THE HEAD BY REASON OF THE CAVING ACCENTUATED AT THIS PART OF THE RAVINE BY RAIN-WATER COLLECTED IN DEPRESSIONS.

process is as natural as the process of decay in a fallen tree. However, we need not concern ourselves with that slow type of washing that takes place on forested lands, provided these are not overgrazed and repeatedly burned; nor need there be much worry about areas well covered with grass, such as that which matted the prairies and much of the eastern plains region in the central part of the United States about two generations ago, *i.e.*, before these vast areas were broken to establish our wheat and corn belts. The evil part of erosion is that which, with the assistance of man and animals, exceeds the natural order of things by upsetting the normal equilibrium between the ground, on the one hand, and the vegetative cover and other stabilizing agencies, on the other hand. It is the excessive washing that has followed the removal of grass, trees and bushes, and the cultivation of steep slopes and lands of excessive vulnerability to washing, without making provision for assisting the disturbed bare soil to hold itself in place that must be dealt with, if the wastage is to be checked.

As a nation we have concerned ourselves exceedingly little about the matter. We have associations for the conservation of wild life, including the flowers, and for the preservation of the gowns of the Presidents' wives; we have established numerous experiment stations in every state for finding out how best to restore the plant food removed by crops, but only one to find out how to retain the twenty-one times greater amount of plant food removed by soil erosion, not to mention the whole body of the soil that goes along with the plant nutrients. But there are no associations for the preservation of the agricultural lands of the nation. We send ships to South America for nitrogen and to Germany and France for potash to replenish our fields, while unconcernedly watching billions of pounds of these materials flowing merrily away from the same fields in rushing rain water. We dig deep into the bowels of the earth searching for stored potash, while that in our soils is being swept away to the oceans.

It is not meant by this that the purchasing and mining of fertilizer materials are to be condemned. They are



A COASTAL PLAIN GULLY

THAT HAD ITS BEGINNING IN A FIELD CUTTING THROUGH WOODLAND.

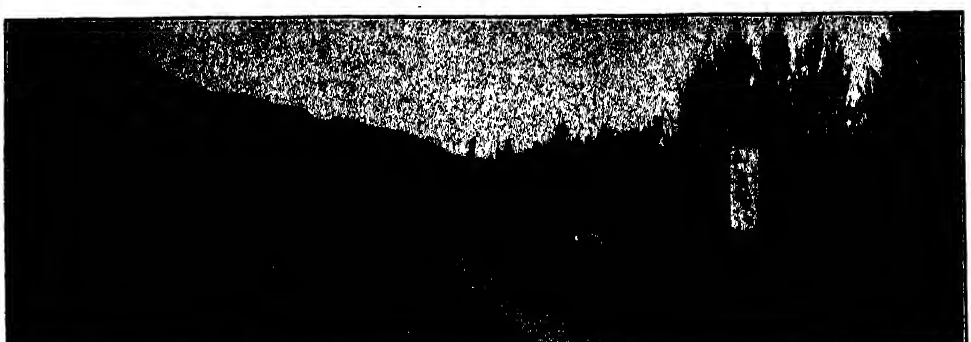
BLANKET OF SANDY OVERWASH

WHICH MAKES THIS PART OF THE SANTA CLARA RIVER VALLEY, EAST OF SANTA PAULA, PRACTICALLY WORTHLESS. THIS STRIP OF RECENTLY DEPOSITED MATERIAL IS ABOUT ONE HALF MILE WIDE.

referred to merely as illustrations of the way nations having abundant resources use them freely, and too often with little thought about conserving them because the other way is easier and because habits generally are not corrected over night. We have accepted land wastage by erosion as something on the order of a natural process, even where its rate has been increased several hundred times by our own handiwork. We have in profound economic discussions referred, often with display of heated concern, to the removal of plant nutrients from the land by the long-continued growing of the same crop as an evil deserving the wicked names, "soil mining" and "soil robbery." We shall not object to this further than to say that soil mining by this process, bad as it often is, is a very small item compared with the operations of the other evil genius that we choose to designate soil erosion. And, too, we shouldn't overlook the fact that plants take out of the soil only the plant food, which can be restored; whereas the villain, wrathful water, takes the plant food and the soil that contains the plant food, which can not be restored.

XI

The erosional-débris discharged into streams does not diminish their volume. The suspended matter, the dissolved matter and the drag material rolling down the beds of the rivers in waves like



ROADSIDE CEMENT GUTTER

PARTLY FILLED WITH EROSIONAL DÉBRIS, AND BEING UNDERMINED BY EROSION, OJAI VALLEY, CALIFORNIA.

MOUNTAIN SLOPE AND VALLEY AREAS OF THE COSTA RICAN HIGHLANDS, WHICH HAVE BEEN IN CULTIVATION FOR NEARLY FOUR CENTURIES WITH PRACTICALLY NO RESULTANT EROSION, BECAUSE OF THE HIGHLY ABSORPTIVE CHARACTER OF THE SOILS.

sand-dunes, most of which comes from tilled lands, abandoned fields and overgrazed pastures, adds to the volume of floodwater very considerably. This is an obvious mathematical truth.

A feature of utmost importance in this connection is the largely increased rate at which water flows off those areas that have had their absorptive mellow topsoil washed off down to impervious clay, rock or incompletely weathered subsoil material. This, coupled with the erosional-débris swept into stream channels, has been the cause of increased floods in many rivers, of increased swampiness over vast areas of bottom land and of excessive surface deposition of comparatively infertile sand, gravel and cobbles over productive alluvial plains and lower slopes.

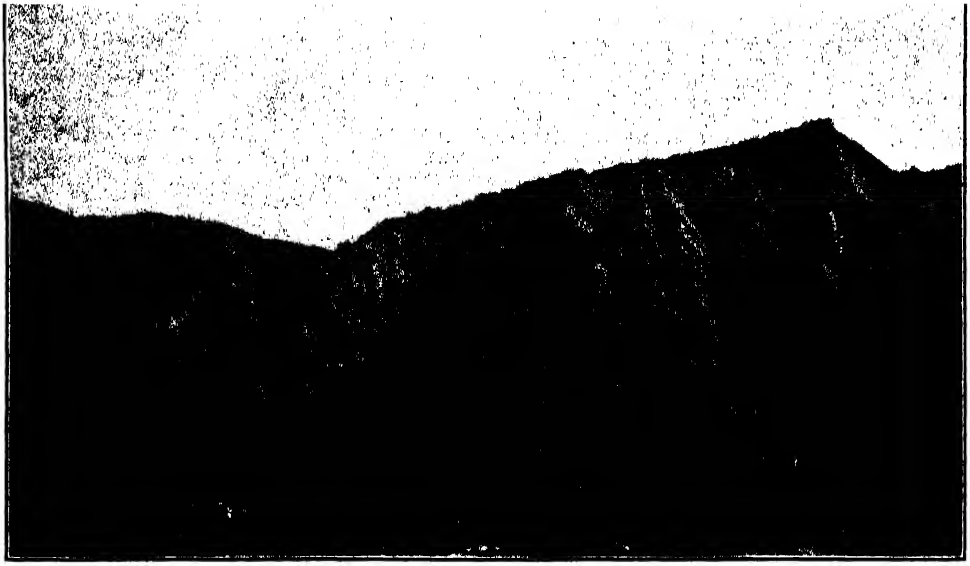
Thus erosion works in the quadruple rôle of increasing the amount of sediments discharged into the streams; of reducing the agricultural value of the eroded uplands; of damaging or ruining alluvial bottoms by overwash and by increased swampiness; and of causing rainwater to flow off impervious washed areas much faster than formerly. This is a serious indictment of the process. But it is none too serious, and unless we do very much more in the future to check the evil scourge than we have done in the past, it can be said now, as previously stated, and without any fear of subsequent punishment for false prophecies, that this country is really but upon the threshold of disastrous soil erosion. This prediction is based upon the fact that subsoil material usually washes faster than surface-soil material and is always more difficult to conserve with the known implements of remedial measures.

XII

What is needed most to conserve soil and soil fertility is a greatly increased use of hillside terraces as a means of slowing down erosion. In the general neglect of studies relating to the fundamentals of the problem, the best thing to do with some peculiar kinds of land has not yet been determined. It is not known, for example, what type of terrace is best suited to a considerable number of these peculiar soils, or, indeed, whether or not any kind of terrace will

THE BEGINNING OF A GROUP OF GULLIES

BY RUNNING THE CROP ROWS UP-AND-DOWN SLOPES GULLYING IS ENCOURAGED, AND OFTEN FIELDS ARE WASHED AWAY UNDER THIS CONDITION BY A SINGLE TORRENTIAL RAIN.



HILL SLOPE NEAR SANTA PAULA, CALIFORNIA

THE EROSION HERE IS TERRIFIC. EVERY YEAR DURING THE RAINY SEASON LARGE AMOUNTS OF MATERIAL ARE WASHED FROM THESE BARE PLACES AND SWEPT OUT OVER HIGHLY PRODUCTIVE VALLEY LANDS TO THEIR DECIDED INJURY. HERE IS A PROBLEM FOR THE PLANT SPECIALIST, *i.e.*, TO ESTABLISH SOME SOIL-HOLDING VEGETATIVE COVER OVER THE ERODING AREAS. PROBABLY OVERGRAZING AND FIRES HAVE CONTRIBUTED TO THE DAMAGE HERE.

save some of them. But it is known that broad embankments, of the Mangum terrace type, are highly effective as conservers of both soil and soil moisture in many parts of the country. In the less steeply sloping fields these embankments can be cultivated over about as easily as any other part of the field. There will be, however, conditions of slope, soil and climate where other forms of embankments must be resorted to for effective results, and no doubt it will be

IN THE UPLANDS

AGRICULTURE HAS BEEN DRIVEN OUT OF THE UPLANDS OF SOME COUNTIES IN THE LOESSIAL REGION BY EROSION. GULLIES AND BROAD WASHES HAVE SO CUT THE LAND TO PIECES THAT ONLY SMALL AREAS OF GOOD SOIL ARE LEFT IN MANY LOCALITIES.

necessary under some conditions to re-enforce these with grass or vines or else to resort to expensive wall-terraces, such as have saved much land in the Mediterranean Basin and in Palestine for more than two thousand years.

Terraces are very practical things. They can be constructed with plows, scrapes and drags at those times of the year when farm work is not pressing. They function much after the manner of hedge-rows and fences in catching and holding soil and moisture coming from slopes above. Being adjusted to slope and soil and having the form of an embankment, they are much more efficient, as a matter of course. They must be laid out correctly, however, or costly breaks will occur. Farmers can be taught how to do this by county agricultural agents, when the latter have been taught how to do it themselves, and that is what is being done in many parts of the south.

For several generations terracing of land has been a common practice on many farms in the southeastern states. At the present time they are being built at a rapid rate in Texas and Oklahoma. In the former state five hundred thousand acres of land were terraced in 1927 under the leadership of one hundred and seventy-five county agricultural agents. The 1928 program for Texas calls for the terracing of one million acres. Even the Federal Land Bank, of Houston, has its terrace expert. If a farmer asks for a loan on his land, the expert looks over the ground to see if it needs terracing. If it does, the work must be attended to before the loan is made. If the farmer doesn't know how, the expert goes out and shows him how to do it.

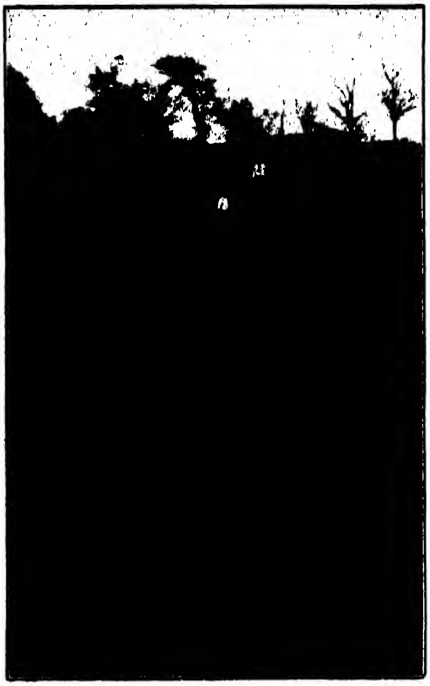
Chambers of commerce, knowing that good yields and productive lands usually mean farm prosperity and that prosperous farmers mean prosperous communities, are very actively pushing this method of land conservation in Oklahoma and Texas. Most of the county agricultural agents in these states and in many of the counties of southern Mississippi and other southeastern states are busy with programs of saving the soil.

In north-central United States, however, probably not one acre in a hundred thousand is terraced. Generally, the farmers of that vast territory know nothing of this highly efficient embankment system of holding the soil; many of them have not even heard of it.

CREEK BOTTOM

COVERED BY SAND WASHED DOWN FROM THE HILLS. THIS AREA WAS BURIED TWENTY FEET DEEP IN FIFTEEN YEARS. IT IS A STRIP OF GEORGIA ALLUVIAL LAND.

There are many sloping fields, however, that can not be protected by terraces. Some types of soil wash too readily for cultivation and should not



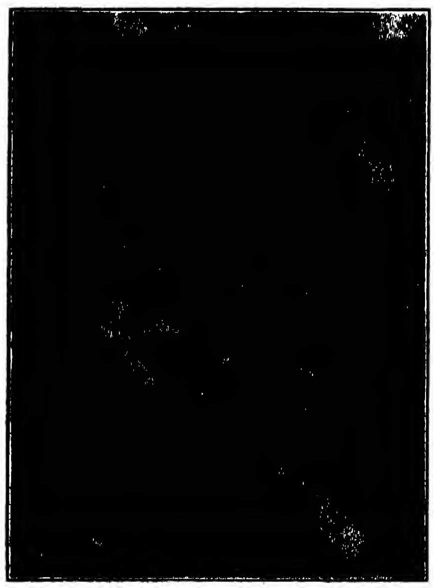
LAND PERMANENTLY DESTROYED BY SHEET AND GULLY EROSION. THIS IS SUSQUEHANNA CLAY OF THE GULF COASTAL PLAIN, A SOIL WHICH IS PECULIARLY SUSCEPTIBLE TO DESTRUCTIVE EROSION.

be tilled under any circumstances. In the Appalachian Plateau fields are still being cleared where the farmers know that but from one to three crops can be grown before the soil washes away.

XIII

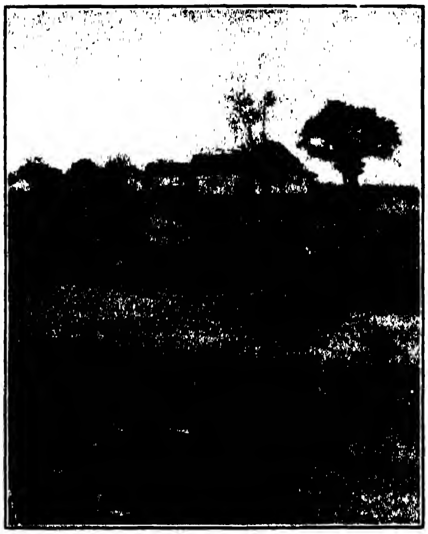
We need to know more about erosional processes. As yet we have measured the rate of washing on but three important types of farm soil of the hundreds of types in the country. We do not even know as yet at what degree of slope cultivation should cease and the land be put into use for grass or trees. We must have these facts. They are fundamental and necessary to both the engineering and agronomic side of handling the problem of land conservation.

When the farmers know what to do they will act. They must have assistance and demonstration of methods, and done to insure the employment of good methods only, methods duly adjusted to varying slope and soil for all the important types of farm land. Terracing, let it be understood, will pay its own way many times over when the farmers have been brought to know what land can be economically protected in this way and how to do the job efficiently. Other engineering means of land protection must be sought in order that gullies may be stopped and filled and that the more vulnerable soils, upon whose steeper slopes terraces have failed, may be saved. Grass and trees must be more extensively grown on the steeper and less stable soils, and crop rotations must be practiced that include soil-improving and soil-saving grasses and legumes.



PROVIDENCE CAVE

SEVEN MILES WEST OF LUMPKIN, GEORGIA. THIS GULLY STARTED FROM THE DRIP FROM A BARN. NOW THE BARN IS GONE AND A LARGE SLICE OF LAND. IN PLACES THIS GULLY IS MORE THAN ONE HUNDRED FEET DEEP. IN THE COUNTY WHERE IT OCCURS SEVENTY THOUSAND ACRES OF FORMERLY TILLED LAND HAVE BEEN RUINED BY EROSION.



EARLY STAGE OF LAND DESTRUCTION BY EROSION ON LAND OF STIFF CLAY SUBSOIL (SUSQUEHANNA TYPE).

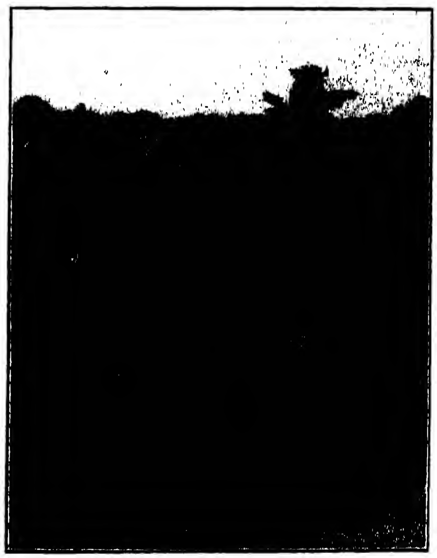
XIV

Finally, we may as well recognize the fact that the evils of erosion are not a matter for future concern only. Thousands of farmers have suffered and are now suffering from the impoverishing effects of rainwash upon the soil. Our better lands have already been put into agricultural use; we are now taking up the inferior grades. Erosion is adding to the area of submarginal and destroyed lands. By increased use of fertilizers and soil-improving crops and with more expensive tillage and abandonment of the more severely washed fields, acreage yields have been fairly well maintained in many farming regions. But the increased cost has brought financial ruin to many farmers.

The viewpoint of business men as to the importance of the problem is clearly revealed in the report of the Business Men's Commission on Agriculture given in a recent publication of the National Industrial Conference Board, which says in part:

The progressive deterioration of our farm lands in this process (erosion) has . . . meant increased difficulties for agriculture, to say nothing of the national injury involved. . . . In the long run erosion is of superlative importance, but it receives comparatively little attention owing to the fact that yields are not greatly diminished until the humus layer is well on the way to exhaustion. The depletion of essential plant foods, through cropping, leads to a cumulative and readily recognizable decline in yields, but soil wastage by erosion, which every year carries away a layer of the surface soil on all areas devoted to cultivated crops, does not appear clearly until the soil grows too thin to furnish adequate nourishment to plants. Unlike the exhaustion of individual elements in the soil, this damage is irreparable, although in a large part it can be prevented by proper methods of cultivation and drainage and by flood control, together with reforestation. . . .

The unavoidable result of this deterioration of the soil is lower yields per acre than would



FORMERLY GOOD FARM LAND UTTERLY RIPPED TO PIECES BY EROSIONAL GULLIES. THIS LAND CAN NOT BE RECLAIMED. IT SHOULD HAVE BEEN SAVED AND COULD HAVE BEEN. MUCH TOO LITTLE IS BEING DONE IN THE UNITED STATES TO PREVENT THIS KIND OF LAND WRECKAGE. THIS IS IN THE REGION OF "BROWN LOAM" (GRENADA SILT LOAM) SOIL THAT COVERS MUCH OF THE UPLANDS BORDERING THE LOWER MISSISSIPPI.

prevail without this factor. The increases in yield made possible by more scientific producing methods are in part wiped out by the progressive exhaustion of the soil, and agricultural costs are therefore steadily increased. Under existing conditions it often may not pay the farmer to use his land conservatively. This is an intricate matter of prices and interest rates, but whatever may be the facts with regard to the costs involved, most farmers seem to be dealing with the question in a manner which involves ultimate exhaustion of the land.

XV

Not a very cheerful picture of our American system of land usage has been painted in this article. With past performances as a background, there is exceedingly little upon which to build a glowing account of our stewardship of the land. However, with the recent soil-conservation activities in Texas, Oklahoma and several other localities, there is good cause to look for a very large expansion in the practice of these commendable methods in the near future, especially if we perform our national and individual duties of helping the farmers.

KNIFE EDGES
FORMED BY EROSION ON GOOD TENNESSEE SOIL.

SHARK FISHING IN THE WEST INDIES

By O. W. BARRETT

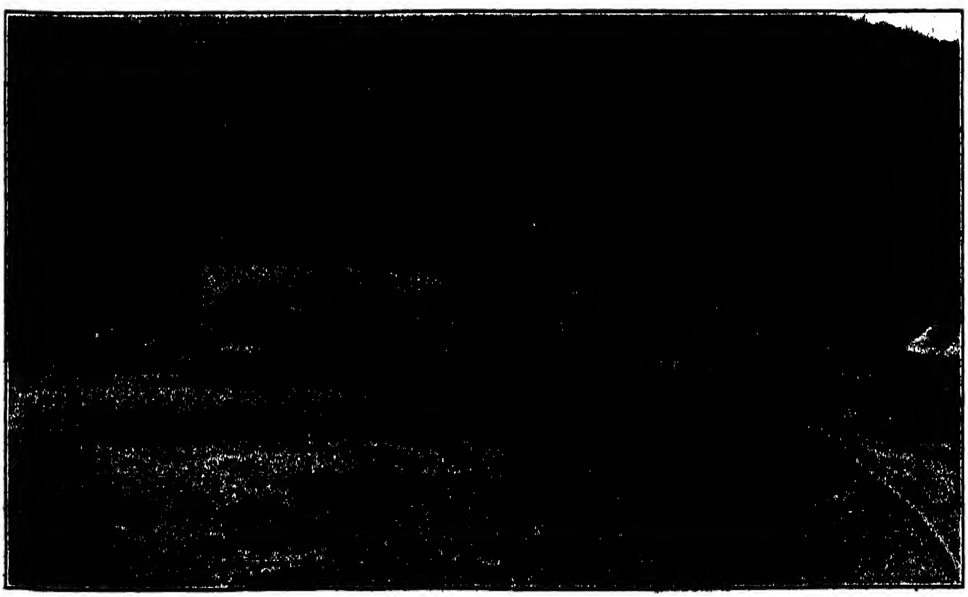
AGRICULTURAL DIRECTOR, DEPARTMENT OF AGRICULTURE AND LABOR, SAN JUAN, PORTO RICO

Of beautiful leathers there is no end, but none better, it seems, than shagreen. For several centuries the bookbinders and curriers have recognized the excellent qualities of shark-skin leather, but only in the last few years has the general public had an opportunity to get the handsome purses, bags and shoes which are now made from the hide of that much hated denizen of the deep.

So many improvements have been made in the *modus operandi* of catching sharks and in utilizing their by-products that the outlook for considerable commercial expansion in that branch of industry is now assured.

Florida has had two or three successful shark-fishing stations for several years, and some desultory fishing has been done in various West Indian Islands, one plant in the American Virgin Islands having spent a large amount of money in installing a modern factory with expensive equipment. There are also projects under way for the establishment of several other stations in Porto Rico, Santo Domingo, Cuba, the British Virgin Islands and Dominica. Most of these West Indian stations will probably not be outfitted to utilize all the shark, but the hide, fins and liver oil can be saved without the installation of special apparatus for drying and grinding the flesh.

The writer, having had some experience in several tropical American countries, believes that the following system will be found most economical: a small building located within reach of fishing boats and so situated that no complaints



AN UP-TO-DATE SHARK FACTORY

THE HIDE HOUSE IS AT THE RIGHT, AND THE OIL AND MEAT MEAL HOUSE ARE TO THE LEFT.

—*Courtesy of W. E. Young*

THE TWENTY-SEVEN YOUNG OF A THIRTEEN-FOOT HAMMERHEAD SHARK

on the part of the public can be made on account of the odors which sometimes are objectionable near such a plant; the fishermen bring their sharks to the plant and sell them at a moderate price—just enough to pay for their trouble; the hides are stripped off and salted down; the fins are removed and

—*Courtesy of E. D. Bellows*

A YOUNG MANTA

OR DEVILFISH, TWELVE FEET IN WIDTH. THE RIGHT CEPHALIC FIN HAD BEEN LOST, PRESUMABLY IN A BATTLE WITH A SHARK. THE SHARK BOAT, PIER AND LANDING DERRICK AT RED HOOK, ST. THOMAS, ARE IN THE BACKGROUND.

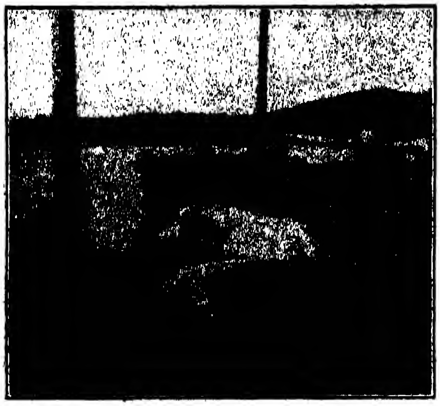
—*Courtesy of C. E. Daniel*
"TIGER" HEAD. NOTE THE NOSTRIL FLAPS

dried in the sun; the livers are rendered, preferably by the bain-marie system or in steam-jacket kettles. The plant can hardly lose any money on the hides, fins and oil obtained by this system; and if circumstances so warrant the plant may gradually expand its operations, installing a drying oven for utilizing the flesh of the sharks and other fish, both for human consumption and for poultry and pig feeds; putting out its own nets and trawl lines in addition to buying sharks and other marine materials from the fishermen would follow in this elastic policy of operation. A plant could be run with only two or three laborers and one superintendent to give a part of his time to the enterprise; or the same unit could be expanded into a factory turning out a ton or more per day of fish meal besides a hundred dollars' worth of hides, fins and oil.

Floating factories are also being tried out, and they may succeed in partly sheltered regions, like the Gulf of Mexico, where schools of many kinds of fish can be "worked" with nets and launches; kettles, presses and steam dryers are rigged up on board so that very little manual labor is required.

Another important factor—and, perhaps, in future work this will prove to be even more important than any kind of shark fishing *per se*—is the making of dried fish fillets. Thick slices of clear white flesh can be taken from the sides of large fish, like the groupers, snappers and the larger kinds of mackerel, as well as sharks, and either promptly frozen or dried thoroughly in a dehydrator. When put in paraffin-paper packages, these "cutlets" are becoming very popular and are a great boon to the housewife who never, under the most favor-

A TWELVE-FOOT GRAY SHARK WRONGLY CALLED "TIGER." NOTE THE NOSTRIL AND TEETH.



GREEN TURTLES FOR SHARK BAIT AT A SHARK PLANT

able circumstances, likes the work of "dressing" a fish herself. Prepared in this way the major portion of the edible parts of the larger food fishes can be saved and put into form for long-distance shipments, the price of these dried or frozen cutlets more than equaling the value of the entire fish as ordinarily placed on the market. The skin, fins and heads when digested in an autoclave yield glue, for which there is always a fair demand; the remainder of the fish dried and ground becomes high-grade poultry feed or fertilizer.

Every shark plant will, of course, have its pressure cooker for extracting the oil from inedible species of fish and

A TYPICAL WEST INDIAN SHARK BOAT

from fish refuse; it will also save the heads, claspers and tails of sharks—which are now wasted—for glue. No farmer likes to have even 1 per cent. of oil in his fertilizer, although, of course, a little does more good than harm if promptly used in poultry feeds. In this connection it is interesting to note that cod-liver oil has proved to be the "missing link" in poultry raising; up to a few years ago there was something lacking in the poultry feeds, now a spoonful of the oil every few days in the pan of mash serves to keep up the vigor of the fowls.

A 150-POUND LEOPARD RAY
THE SHARK'S FAVORITE FOOD. NOTE THE RINGS AND SPOTS FORMING A BEAUTIFUL PATTERN.

There are hundreds of suitable sites around the Greater and Lesser Antilles, to say nothing of the Caribbean and Gulf Coasts of the mainland, where from three to six sharks on an average may readily be taken every day in the year without materially affecting the supply.

There is no more attractive work and the industry would not only give employment to a very deserving class of people but would probably yield better profits on the capital invested than would any other similar enterprise.

In the Sulu Archipelago of the southern Philippines there are several places

where Moro fishermen make a good living merely by taking the fins of certain species of sharks and drying them for the Chinese trade. In some of the Arctic regions the Eskimos also do well at catching sharks simply for the oil of their livers, and this system has been duplicated in various other regions, notably off the West Coast of northern South America, where the basking shark may be taken at times in large numbers, each fish yielding from forty to over one hundred gallons of oil from the large liver.

There are other localities where sharks are taken for their skins alone. Factories are now being installed, however, wherein practically all parts of the shark will be utilized. The skin will be the principal item and its value should average about two dollars for "general run" grays of seven to nine feet; that from large "tigers" and hammerheads may be worth five dollars or more if the skin is in good condition. Fortunately, the skin of the commonest species, the "gata" (cat), or nurse shark, is the most valuable for shoe leather; its tensile strength is six to ten times that of ox-hide.

The second item in importance will be the liver oil. At present the price of shark-liver oil is very low because it has to compete with ordinary fish oil in the open market. This status is gradually changing, due to the fact that poultry raisers and others are recognizing the fact that the oil from shark livers ranks with cod-liver oil as a cheap and safe source of vitamins; all the principal vitamins A, B, C and D, are contained in shark oil, D being the most important, perhaps.

The fins come third in importance in the shark raw materials. The price varies greatly from a few cents apiece in case of the common nurse sharks of tropical waters to two dollars or more per pound for the gelatinous fins of the sawfish shark.

The last, but in some ways the most important, part of the shark to be considered in the modern plant is the meat; the meal, made by thoroughly drying the flesh and then grinding it, is a first-class feed for poultry and pigs. Strange to say, little effort has been made to save the meat of sharks in most localities, although one or two factories in Florida have successfully sun-dried large quantities of shark meat for human consumption; the Belgian Congo consumes very large quantities of salt shark meat. One out-of-the-way place in Porto Rico has for years been producing quantities of dried shark meat in competition with salt codfish, one of the principal imported foods of the island; the fins, livers and even hides at the said place are thrown away and only the large pieces of firm, boneless, white meat running from the shoulder to the middle of the body are removed and hung on wires to dry in the sun and wind—there being practically no rain at any time of the year in that locality. Fresh shark meat is commonly sold in the markets in most Antillean seaports, and its popularity seems to be increasing.

Instead of expensive and complicated vacuum dryers which have been used for this purpose, the shark meat merchants of the future will probably use some form of steam-pipe hot-air oven dryers. In this apparatus the meat, cut up in chunks, or, if for human food, in fillets, is put into wooden trays having galvanized-iron wire-mesh bottoms; and these trays fit into a huge box-shaped oven which is heated by horizontal coils of steam-pipe placed in five or more tiers between the trays. By keeping the temperature in the oven below 180° F. the vitamins in the meat are largely retained and the very high protein content is saved. Probably no other food product in the world is so rich in protein as shark meat meal; whereas dried blood and the best forms of tankage contain only about 60 per cent. to 70 per cent. protein, this

shark meal contains 75 per cent. to 91 per cent. In fact, it is so rich that it is now being used as a poultry tonic, and thus it stands outside of the class which is represented by ordinary slaughter-house tankage and "scrap" meal from the fish canneries and fish-oil factories.

Three plants for the manufacture of fish meal and fish oil are now being installed, one in Maine, one in Florida and one just over the line in Lower California; the latter factory will probably be one of the largest of the kind in the world, and will have a capacity of ten tons of meal per hour, according to reports.

Improvements in the methods of catching sharks are gradually being worked out. The most efficient method of capture is the set net. A net, from three hundred to five hundred feet in length, is stretched across areas where sharks are known to run, the bottom edge being anchored and the top edge buoyed by floats. Most sharks, when attempting to go through the net, get the strands, which are about twelve inches apart, caught in their gills and, strange to say, this soon causes them to "drown."

Trawls are also used: large specially tempered steel hooks, mounted on chains attached by swivels to the main line, are placed at intervals of a few yards along this trawl line. When properly baited and well set a good trawl line may catch from three to nine sharks at a setting; the trawl should be taken up every few hours in order to prevent the sharks caught on the hooks from being attacked by other sharks. New kinds of shark hooks are being tried out: it requires a high grade of steel to hold a one thousand-pound fish without breaking or straightening out.

In many places it is possible to harpoon sharks from a launch or rowboat; and on the east coast of Nicaragua the writer has seen sharks harpooned by a native standing in the surf; one man usually can pull in a seven-foot specimen, but two are needed for an eight-footer. In some places large numbers of sharks have been taken by the rather reprehensible method of baiting certain areas with fish offal and when the sharks which are attracted thereto are massed around the spot a stick of dynamite is thrown into the school and the stunned sharks are then lassoed or harpooned as they float, white bellies up, on the surface.

A Porto Rican shark fisherman has perfected a killing lance which makes it safer for the fisherman to handle these half-dead but very dangerous animals. The peculiar-shaped lance attached to a stout bamboo handle enters one of the gill slits in the side of the neck, and a twist of the wrist severs the main artery in the throat.

Another very interesting method of catching sharks has been in use on the south side of Porto Rico, where the nurse shark comes to breed in April, May and June around the reefs and in the lagoons. Men armed with ropes, clubs and "machetes" wade out into the shallows where the sharks are congregating and at that time they have little difficulty and practically no danger in taking large numbers of these animals, which are then hauled away in trucks and used as fertilizer in nearby fields.

It is a remarkable fact that after so much study has been put on ordinary fishes there should be such a lack of knowledge concerning the shark fauna of these tropical localities. We are just beginning to learn that there are not merely three or four species, as formerly believed, but actually ten or a dozen distinct commercial kinds of sharks, which inhabit the waters of the West Indies as well as the East Indies. Four or five of these species are more or less common throughout the year around the Antilles, while others are occasional visitors that come in from deeper waters to breed on the reefs and in the bays at certain periods.

The two commonest forms in tropical American waters are the nurse (*Ginglymostoma cirratum*) and the blue gray and dusky sharks (*Carcharhinus* and *Carcharias* spp.). There seems to be only one kind of the former, while there are at least three of the latter group. The so-called "tiger" (probably a *Carcharhinus*) is also common but never dependable—he is a routsabout traveler, while the gatas are reliable stay-at-homes and the grays are respectable middle-class folk. The sawfish (*Pristis pectinatus*), so common around Florida, the Nicaraguan coast and along northern South America, is strangely absent or very scarce in the Antillean regions. The hammerhead (*Sphyrna zygaena*) is a queer old fellow with many good qualities, when he can be found—and where; his hide is not so tough as that of the gata, but there is usually much more of it—being two or three times longer.

Related to the sharks, but of very different habits and shape are the rays. One of the commonest and most widely distributed fish in the Tropics of both hemispheres is the leopard ray, or chucho (*Aëtobatus narinari*). This excellent and very beautiful food-fish lives on the bottom at a depth of from two to five fathoms and eats mollusks and other marine animals which inhabit the ocean floor. The body of a ray is roughly triangular in shape and flattened like a flounder; the tail is reduced to a sort of whip which, however, may attain a length of six to ten feet or more. On account of their habit of lying half concealed in the mud, the rays have adopted a special manner of breathing: the water is taken in through circular apertures on the upper surface just back of the head and is expelled through slits on the underside of the body. The flesh of the chucho is of excellent quality, and it should be dried or frozen in fillets for human consumption. Its skin, covered with grayish-blue circles and spots, will some day be very popular.

The king of all rays is the eagle, or manta ray (*Manta birostris*) which is fairly common throughout the Caribbean and Gulf of Mexico. This so-called devil-fish attains a spread between the tips of the so-called "fins" of twenty-three and one half feet or more, the thickness of the body of such an animal, however, being only about three and one half feet. The weight of these large rays is about double what it appears. A small chucho of only five feet in width tips the scale at over 150 pounds, while a full-grown manta would probably weigh three or four tons.

In both sharks and rays there are no small bones as in ordinary fish—not even in the fins; the shark backbone is of a brilliant white color and when properly dried and held straight by means of an iron rod run through its center this object makes a very interesting and deservedly popular cane; the joint sculpture is decorative and the brilliancy of the ivory is remarkable.

The teeth of the common shark are unlike those of any other animal in the world; being composed of nearly pure enamel they are practically indestructible and their astonishing abundance in certain geological strata gives proof of the quondam great abundance of sharks, some of which must have attained a length of eighty feet in the Devonian era.

By the way, mounted on pieces of turtle shell, these shark teeth make excellent watch-fobs; their indescribable shape, brilliant white color, and serrate, curved edges make very attractive ornaments.

After some twenty years of experience with sharks the author has only just recently learned that a shark's tooth is a three-bladed razor: the glass-like enamel on the edge of each finely serrate denticle on all of the three sides of the tooth will cut a hair, just like a piece of glass. Incredible as it may seem, it is possible to scratch glass with the serrate edge of a

shark's tooth; it would appear, therefore, that shark-tooth "enamel" is the hardest animal substance in the world. The Boy Scouts are going to have some fun with their shark-tooth watch-fobs, which we understand are given away with each pair of shark-skin shoes.

There is a mystery about the shark's digestive function; the stomach is better than that of most fishes, the pancreas is good, the liver is excellent and serves not only to aid the gastric action but also stores up fat to carry the body over periods of food shortage; but when we look for the intestine we find only a complicated spiral valve-like organ and an excessively short, thick-walled tube—only two or three feet long in an eight-foot shark, while the alimentary canal of a porpoise, of the same size and living on just the same sort of food, measures over seventy-five feet in length.

With the possible exception of some of the turtles, for instance, the land tortoises of Tropical America (which are in some countries fattened up on sweet potatoes, their enlarged livers then constituting the famous dish, maracoy ragout, than which there is none better in the whole wide world), there is no liver so large in proportion as that of the common gray shark. A shark seven feet long and weighing about two hundred pounds has a liver, usually in two or three long lobes, which practically fills the entire abdominal cavity and may weigh twenty to thirty pounds. The gall bladder, however, is comparatively small. The oil content is so great that even the heat of the hand starts the oozing of the oil.

There is also a deplorably large shadow zone around our knowledge of sharks' breeding habits. Why do some sharks lay large four-cornered eggs while others give birth to their young in quasi-mammalian style—nourishing the sharklets within the female's body with a milk-like substance so that they are able to swim away on their own power at birth? In the shark and ray systems of reproduction all the eggs are fertilized—a much more economic arrangement than that which obtains in the case of nearly all other groups of fishes.

Coming back to the original point, the peculiar grain and sheen of shark leather, curried or uncurried, make it especially adaptable for cigarette-cases, purses, ladies' bags, belts, book-bindings, etc., while the regular-grade leather is now made up into shoes; these seem to outwear any other kind of leather. Shark leather does not scuff like other leathers. Its surface never checks, cracks nor "roughs up," and it seems to endure wetting and drying better than bovine leather. Formerly it was very difficult to work shark skins due to the fact that in most species there are flakes or spicules of lime embedded in the outer layer of the skin. So rough is this outer skin (sometimes called the "shagreen") of some species of sharks that it may be used in polishing wood or metal in place of sandpaper. A new patent "acid" process, however, removes the lime and leaves the skin pliable without destroying the peculiar "pattern" of the surface and its pleasing luster.

The color of shark leather varies greatly from a grayish or pale-brownish shade to a dark greenish or almost black color. By varying the kind of tanning material the shade can be changed artificially to meet the most fastidious public taste. We have long been accustomed to alligator leather, which has a much bolder "pattern" than that of the shark, but lacks the wonderful luster. Lizard skins have been popular for purses and small bags for years, and long ago the Japanese learned how to prepare the skins of large toads for such purposes.

Instead of slowly drying the fins on racks in the sun it is recommended that they should be quickly and completely

dried in hot-air ovens. When the moisture content is brought down to around 10 per cent. these fins can be packed in boxes, barrels or bales and, if protected from the weather, can be shipped halfway around the world without deterioration. An expert Chinese cook, given two days for the work, can make a soup from shark fins which can not be excelled; the gelatinous rods become quite transparent and the peculiar delicate flavor is even better than that of the famous bird's-nest soup, for which Chinese epicures pay exorbitant prices; fin soup, particularly the "boon-leong-sit" variety, may be worth five Hongkong dollars per bowl: it is supposed to possess highly invigorating qualities.

England now seems to be vying with America in the utilization of shark meat as well as leather; it is reported that one to two hundred tons of "rock salmon," or shark meat, are consumed daily in the London district. By the way, the flavor and texture of shark meat is somewhat like that of halibut. The writer regards young hammerhead as the best food shark.

Now that we have learned how to obtain sharks in large quantities much more cheaply than heretofore the public should in the next few years have an opportunity to obtain several times as much shark leather as in the past.

It is difficult to explain just why sharks are at present so much in the limelight; but it may be that there is a decided pull, so to speak, both on the part of buyers of shark leather and the users of shark by-products, such as liver oil, meat meal, etc., and also a push on the part of the producers; they are now anxious to *sell* the sharks which they have been catching and throwing away. Logically, a purse or hand-bag with the distinctive "shark sheen" will outsell the ordinary article anywhere; and very naturally the fishermen are tired of pulling up their hooks and finding that the sharks have taken bites off the fish on the hooks, broken their fish-traps and frightened away the best kinds of food fish; and when they can sell one of these murderous marauders for a dollar or two at the factory instead of throwing him back for his cannibal brothers to eat—then the business begins to grow.

Finally, the main point to consider is this: we now have ways and means of utilizing sharks commercially, we are learning how to take them cheaply, and we know that by removing them from the sea we are directly saving other fishes. And while it is hardly possible to successfully operate a factory which depends on sharks alone we are coming to see that a combination of other marine products with sharks, when properly handled in an up-to-date plant, may be considered as one of the richest "strikes" in the only inexhaustible mine—the sea.

We have been hating sharks on general principles for centuries, and in some ways they have deserved it; but now it is high time that they should pay up. There are no more interesting animals in the world, and the ways and means of turning them into cash constitute one of the most fascinating of our modern industries.

THE HIGH ATMOSPHERE OF THE EARTH

By E. O. HULBURT
NAVAL RESEARCH LABORATORY

The earth on which we live has recently been called a "seventh of a second earth," by Professor Kennelly, of Harvard University, having in mind the fact that by means of wireless telegraphy one can communicate with any portion of the earth in less than a seventh of a second, for this length of time is required for the wireless waves to encircle the globe. It is true that the wireless waves have furnished a marvelous method of communication, but they have done more than this, they have by their behavior led to information about the high atmosphere of the earth, those cold and rarefied regions several hundred miles overhead. It is really quite a long story, and at the present time it seems that we are in the midst of one of the most exciting chapters with perhaps but a dim perception of what the end will be like. It may be said that the high atmosphere, which heretofore has been a rather elusive and unexplored part of our earth, has become of importance in everyday life. The wireless engineer at any rate knows that he is absolutely dependent upon it for signals which he expects to send or receive at distances greater than a few hundred miles, and that he must in the end understand as much as possible about it for the development of his craft.

For a long time knowledge of the upper reaches of the atmosphere has been very fragmentary, indeed; it has depended on small groups of outlying observations together with much theory and speculation. The pressures and temperatures of the lower atmosphere have been investigated directly by means of small balloons carrying recording instruments to heights of twelve miles or so. The curves are extrapolated to greater heights, with full realization that possible errors may enter increasingly the higher one goes, so that at three hundred miles, let us say, one can have no great confidence in their correctness. The appearance of meteors, their brightness and the length of their trails furnish evidence sometimes confusing and contradictory of the pressures and temperatures of the high atmospheric gases. Certain absorption bands in the spectrum of the sun, particularly in the ultra-violet region, show that there is ozone in the atmosphere fifty or a hundred miles overhead; there is no appreciable ozone in the lower air around us. The polar light or aurora and the dim greenish light of the night sky between the stars which comes from our own atmosphere give evidence that some sort of electrical and light-producing action is present in the upper atmosphere. All these things are beyond our control; one merely observes them and makes what inferences are possible. With the advent of the wireless waves, however, there has come into existence for the first time a controllable means, and a powerful one, of plumbing the outer depths, just as sound waves are being used to search the earth beneath our feet.

We must go back to the year 1901 when Marconi, in his transatlantic signalling experiments, demonstrated for the first time that the wireless rays could bend around the bulge of the earth. Lord Rayleigh immediately raised the question as to how this could be. In answer Kennelly in this country and Heaviside in England independently suggested that there were electrons and ions in the high atmosphere which bent the wireless rays back to the earth again, so that the ray traveled over the earth

by successive reflections between the earth's surface and the electrified atmospheric layer, somewhat as it would do between two parallel sheets of metal. (It may be well to mention that electrons are small negatively charged particles of electricity; ions are electrically charged gas molecules or atoms, usually positively charged, although sometimes they are negatively charged. The electron is much lighter than the ion, weighing only about a ten thousandth as much. The charged particles, ions and electrons are spoken of as the "ionization"; an "ionized" gas is one in which there are a number of such charged particles.) In the following twenty years commercial wireless telegraphy developed rapidly and many new facts were brought out, but in spite of this wide technical extension little advance was made in an exact understanding of the propagation of the waves. The proper facts to give the clue were still lacking. These were finally brought to light in the discoveries of the remarkable behavior of the short waves, waves below fifty meters in length. These discoveries, demonstrated by the amateurs all over the world in the years around 1923, were developed systematically by the far-flung organization of the United States Navy.

The short waves were found to skip over regions near the transmitting station and to come down to earth again several hundred miles away. Around the transmitter there was thus a small zone of reception which soon yielded to a zone of silence which in turn was surrounded by a zone of reception. The widths of the zones of silence, or the "skip distances" as they are called, were measured for each wave-length (the skip distance increased as the wave-length decreased). These measurements showed unmistakably that in the high atmosphere there was an electron and ion layer which set in at about fifty miles above the earth and which increased in density with the height until at about 120 miles, in the daytime, there were about a million electrons per cubic inch. There is nothing unusual, of course, in this number of electrons, the number of air molecules at this height is ten million times as great and at the earth's surface is a hundred million millions times as great. Above 120 miles the electrons decreased in density, but beyond yielding this simple fact the wireless rays were powerless to tell more about this region of the atmosphere. Because any ray which penetrates to these levels is unable to return to the earth, it probably goes out into interplanetary space; at all events it is lost to us as far as we can tell now.

The skip regions of the short waves, although of great theoretical interest, were not the sort of thing to command the practical use of the short waves. If this were all they had to offer their commercial development would have ceased at once. They possessed, however, the ability of traversing great distances over the earth, with the result that communication by means of the short waves half way around the earth is now accomplished with astonishingly little power, a hundred watts or so, in the transmitter. With somewhat more power, several kilowatts, the short wave signals have been observed to pass three times around the earth before being weakened to indistinguishability. The reason that the short waves could easily reach distances quite inaccessible to the long waves was mainly that they passed through the high atmosphere with much less absorption of their energy than was the case for the long waves.

Since the wireless waves had not only given definite proof of the electrification of the high atmosphere, but had told within limits how many electrons there were and how high above the earth's surface the electron and ion layer was, the question as to the cause of the electrification was investigated. It was almost obvious from the start that the

ionization was due for the most part to the ultra-violet light of the sun, because practically all the wireless phenomena, such as ranges, skip distances, etc., changed in a regular manner from day to night and from summer to winter. Furthermore, it is well known that ultra-violet light of a suitable wave-length tears apart neutral molecules and atoms into negative electrons and positive ions. There was, of course, the possibility that other agencies, perhaps of radioactive nature in the earth or the sun, or of unknown origin, might have an important influence on the electrification. The matter resolved itself into dragging out all the lore of the laboratory which had a bearing on the case, such as the intensity of the sun's ultra-violet light, the electrification of gases by ultra-violet light, the diffusion of ions under the influence of the magnetic field of the earth, etc., hammering through the mathematics and calculating the ionization. Many facts necessary to an exact calculation were imperfectly known, but within this uncertainty the calculated ionization due to the ultra-violet light of the sun agreed as closely as could be expected with that given by the wireless waves. The conclusion was that the sunlight in the far ultra-violet was a necessary and sufficient cause of the ionization of the high atmosphere and that other ionizing agencies were uncalled for.

Since the calculated ionization in regions below 120 miles agreed well enough with the wireless phenomena it was possible to take up with some confidence the calculation of the ionization at greater heights than this in regions which as yet are unapproachable by direct experiments. The result came out that the electron density, which at 120 miles was a million electrons per cubic inch, decreased at 145 miles to a hundred thousand and at 170 miles to ten thousand. It seems fairly certain that the electronic densities for the greater heights are, if anything, underestimates. In these high levels where the atmosphere is very rare indeed, the pressure being a million millionth of the sea-level pressure, it was immediately evident that the electrons and ions would behave differently from those in the lower levels. For a charged particle will, if unhindered, move in the general direction of the lines of force of the magnetic field of the earth.

In the regions below about 120 miles the gas pressure is relatively high and the ions and electrons there are jostled about so frequently and so irregularly by their collisions with the gas molecules that they have no opportunity to be influenced by the earth's magnetic field. At greater heights, above 150 miles, where the gas pressure is much lower and collisions are rare, the ions and electrons move undisturbed in the direction of the magnetic field, and therefore they migrate to the magnetic poles of the earth and accumulate there. It does not take them very long to do this; their velocities are around a mile a second and they can move from the equator to the poles in two or three hours. In the polar regions the lines of magnetic force descend downward almost vertically towards the earth, and the ions and electrons are guided to lower levels. There, because of their increased concentration and the greater gas pressure, they recombine to form neutral molecules again and in some way set free their electrical energy of recombination to give the aurora light. Thus the energy of the aurora comes indirectly from the sun; the energy of that portion of the sun's ultra-violet light, which is absorbed at high levels in the sun-lit regions and causes the upper spray of the ionic layer, is transported to the polar regions and reappears (or a portion of it does) as the aurora. The ions may be regarded as being vaporized in the high atmosphere and distilled along the lines of magnetic force to the poles where they condense to neutral molecules again and yield up their energy of formation as

aurora light. Because of winds in the high atmosphere of the earth and of variations in the sun's radiation due to sun-spots, etc., the ion layer is probably not uniform but is a thing of shreds and patches. Upon drifting to the poles the patches lengthen into streaks and being touched into luminosity form the auroral streamers.

The total energy in the aurora light showered down to the earth during a strong display of northern lights has been shown to be at the rate of one hundred thousand horsepower; just about this amount of energy is available in the upper layers of the ionization. This is really seen to be a small amount of energy when it is remembered that the total energy received from the full moon all over the earth is at the rate of a hundred million horsepower, and from the sun is a million times this. All in all this theory of the origin of the aurora is in keeping with present-day knowledge; it can, however, hardly be said to be completely established as yet. It suggests, and must wait for the results of, many laboratory experiments on the electrical and light-producing effects in the atmospheric gases at low pressures. The aurora itself should be surveyed with the spectroscope under a large variety of conditions. Its energy should be measured, and in many ways it should be subjected to closer scrutiny than has been done up to this time. The spectrum of the south pole aurora has never been taken at all, although to be sure there is no evident reason why it should differ from that of the north pole.

To return to the ionized layer in the polar regions—because of the contour of the magnetic lines of force the ion and electron cloud would be expected to form a sort of large-stemmed mushroom over the magnetic poles, the stem of course not actually reaching down to the earth's surface but beginning fifty miles or so above the surface. The stem will perhaps be several hundred miles in diameter. Wireless waves striking the sides of this stem might be reflected back on their course and certain experiments of the Navy indicate that this may happen. The experiments consisted in transmitting short pulses of wireless waves and measuring the time for the echoes to return from the north. The time interval gave a distance about equal to the distance to the polar electrified mushroom. One can not be sure yet that these experiments have demonstrated conclusively the existence of the ionic mushroom, for the echoes may possibly have come from inequalities of the land or the waves of the sea. (From the rather easy way in which this is written one should not suppose that idle speculations are being tossed about. Every phrase has withstood severe criticism, and practically every statement has mathematical and experimental justification). The final answer can only come from continued experiment, particularly at or near the magnetic poles of the earth. With transmitters and receivers of wireless signals in these regions programs of experiments similar to those already carried out in more temperate latitudes would certainly yield information of the greatest importance and might furnish the key to the exact interrelation of wireless telegraphy, the aurora, the ozone, the magnetic storms and other phenomena.

It is interesting to look back upon these developments, which have been followed quite blindly with no notion where they were leading. One wonders what their future will be. We see now that they all point to the magnetic, and possibly the geographic, poles as being the regions where the most interesting things may happen and where experiments might be expected to yield the most fruitful results. In conclusion, it is hardly necessary to mention that the high atmosphere is not the only field of inquiry which may look for wide extension from polar investigations.

INFLUENCE OF CRYSTAL STRUCTURE ON ELECTRON EMISSION FROM METALS

By Professor H. E. FARNSWORTH
DEPARTMENT OF PHYSICS, BROWN UNIVERSITY

WHEN electrons are shot against a metal target in an inclosure from which the air has been removed as completely as possible, it is found that some of these incident electrons (which will hereafter be called primary for convenience) are turned back from the target without loss of energy, that is, the direction of their motion has merely been changed without changing their speed. It is customary to refer to these electrons as reflected electrons. Others of these primary electrons make collisions with electrons in the metal, giving up energy to the electrons that are hit which, in many cases, is sufficient to completely remove these electrons from the same surface of the metal which is struck.

This discussion applies to a piece of metal of sufficient thickness so that no electrons are able to pass through it. All those electrons, including the reflected ones, which escape from the metal (hereafter to be referred to as secondary electrons) do so from the surface of the metal which is struck by the primary electrons. In order that an electron may escape from a metal surface it must have sufficient energy to overcome the attractive force which tends to hold the electron in the metal.

The electrons which are knocked out of the metal have speeds much less than those of the primary electrons. This difference in speeds is a criterion for differentiating between the reflected electrons and those which are knocked out of the metal. It is true that there is a certain ambiguity, inasmuch as some of the primary electrons which lose energy by collision may still retain sufficient energy to escape from the metal with a lower speed than they originally had. Hence, the single fact that electrons leave the metal surface with speeds much lower than those of the primary electrons would not enable one to decide whether electrons are actually removed from the metal or whether these low speed electrons are merely original primary electrons which have given up some of their energy on collision. There is, however, definite proof that electrons are actually knocked out of the metal, since for certain primary electron speeds, such as produced by a battery of a few hundred volts, more electrons have been found to leave the metal surface than strike it. This leaves no uncertainty for the primary speeds at which this occurs.

That electrons are also knocked out of the metal for a considerable range of lower primary speeds appears certain because of the manner in which the speeds of the secondary electrons are distributed. As previously mentioned, there is a group of reflected electrons leaving the surface which has lost no energy. There is also a general distribution of electron speeds extending over the region below the primary speed, which is undoubtedly due to electrons that have lost various amounts of energy on collision. In addition, there is a group of low speed electrons which increases in size as the relative number of electrons leaving the surface increases. It is this group which consists of the electrons that have actually been knocked out of the metal.

The question as to the minimum incident speed which is required to remove an electron under given conditions, although of great importance, is not so easily answered. However, it appears

that a minimum speed is required, for, unless the incident speed is greater than a certain value, no electrons with speeds appreciably less than that of the primary electrons are found to leave the metal. We, therefore, conclude that under these conditions no electrons are knocked out of the metal, even though some of the primary electrons fail to return. The minimum incident speed for which low speed electrons begin to leave the surface ought then to be that required for the removal of electrons from the metal. Unfortunately the incident speed at which this occurs is not sharply defined, so that an accurate determination of the value is impossible.

Experiment shows that the secondary electron characteristics vary greatly with the conditions under which they are obtained. All metals ordinarily have large quantities of gas adhering to their surfaces and distributed throughout their volumes between the metal atoms. A large part of the gas may be removed by prolonged heating of the metal in a vacuum at temperatures near the melting point of the metal. This removal of gas changes the secondary electron characteristics, but after heating the metal for some hours in a vacuum a condition is reached such that further heating produces no perceptible change in the results obtained.

In experiments of this sort, the source of electrons is usually a heated filament similar to that used in radio tubes. The electrons are accelerated by means of a battery to a diaphragm with a hole in it. Some of the electrons pass through the hole, thus forming a sharply defined electron beam of uniform speed. The speed of the electrons may be varied by changing the size of the battery. The target to be studied is placed in the path of this electron beam. By surrounding the target with a metallic spherical shell, the electrons which come off the target may be caught and measured with a sensitive galvanometer. By applying various electrical potentials to the collecting sphere and measuring the corresponding electron currents, one obtains a measure of the relative number of the secondary electrons which have various speeds. The whole arrangement, with the exception of the galvanometer, is enclosed in a glass tube from which the air has been as completely removed as possible.

Any one not familiar with this particular field of investigation may well ask what is to be gained from a knowledge of the characteristics described thus far. It has appeared for some time, to those competent to judge, that these characteristics when free from the effects of gas are distinctive of the atoms of the metal in question. The relation between the number of electrons leaving the metal and the speed of the primary electrons changes suddenly at certain critical speeds. This fact has been taken to signify that the atoms respond, when struck with electrons of these critical speeds, in a manner such as to effect an alteration in the number of electrons leaving the metal, and that this response is a characteristic of the external structure of the atom itself. If this view is correct, a determination of these critical speeds would then furnish information regarding the external structure of the atoms of the metal. This information would pertain only to the exterior regions of the atom since the present discussion is confined to relatively low speed electrons which are unable to appreciably penetrate the interior of the atom. These are relatively low speed electrons when viewed in the perspective of electron speeds easily attainable, although the very low speed which is acquired by an electron falling through a potential difference of only one volt is approximately 370 miles per second.

The data which have been obtained up to the present time by different observers are largely discordant. A part of the disagreement appears to be the result of different amounts of gas present in the

metal in the different experiments, but recent results of the writer[1] show that, in addition to gas, there is another factor of a very fundamental nature which has an enormous influence on the characteristics, at least for the lower electron speeds. This other factor is the arrangement of the atoms at the surface of the metal with respect to one another. Although each metal has a definite crystal structure, in an ordinary sample the crystals are broken into very small pieces and oriented at random. If the metal is heated near the melting point for a considerable length of time some of these crystals grow larger at the expense of their neighbors. After copper has been heated at red heat for an hour or two in a vacuum, the single crystals at the surface are large enough to be easily visible with the naked eye. Thus when a metal is heated in a vacuum, not only is a considerable amount of gas removed, but the arrangement of the atoms with respect to each other changes.

Various results by the writer had indicated that the secondary electron current is in some way dependent upon the arrangement of the surface atoms, but definite proof of this was recently established when the secondary electron current as a function of primary speed was obtained for a target cut from a single crystal of copper. This relation was found to be distinctly different from that for an ordinary or polycrystalline sample of copper. Evidence of the influence of structure was also obtained from the characteristics of a target of phosphor bronze which contained more than 95 per cent. copper. If the results are distinctive of the atoms independent of their arrangement, then the results for a target containing over 95 per cent. copper would not be expected to differ appreciably from those for pure copper. If, however, the arrangement of the atoms is a determining factor, the presence of a small percentage of other atoms might be sufficient to produce considerable changes. The results obtained for phosphor bronze were distinctly different from those for copper in the ordinary, or in the crystalline form, showing that the modified atomic arrangement must be responsible for the change.

These experiments were not extended to primary speeds greater than that corresponding to about forty volts, so that it is impossible to give the maximum speed to which this applies. It appears probable, however, that this effect is confined to relatively low speeds.

The effect of atomic arrangement on the secondary electron current is not necessarily at variance with the view that the secondary electron characteristics are distinctive of the structure of the atoms. It may simply mean that the outer structure of an atom, which is the only part here effective because of the low speeds of the primary electrons, is dependent upon the arrangement of the neighboring atoms. That is, the outer energy levels of any one atom may be modified as a result of the close proximity of neighboring atoms and thus be a function of the environment of the atom. Should this prove to be the correct interpretation, it follows that all other phenomena which are a function of the outer energy levels of the atom must also be affected by atomic arrangement. It appears that some of the discordant results in the field of soft X-rays may be accounted for in this way. This remains for future work to decide.

The experiments described here, however, have definitely proved that the arrangement of the atoms in a metal is a determining factor for certain phenomena which were formerly attributed to the individual atoms independent of their environment.

[1] *Phys. Rev.*, Mar., 1928.

MATHEMATICS IN BIOLOGY

By J. ARTHUR HARRIS
UNIVERSITY OF MINNESOTA

WHAT is mathematics? And what right has mathematics to obtrude itself upon the attention of biologists?

Since mathematics is a very old science, inextricably bound up in its historical development with logic and philosophy on the one hand and with astronomy on the other, it is perhaps impossible to give a concise definition which would satisfy the workers in all its fields, theoretical and applied. It is easier and more pertinent to our present purpose to indicate some of the characteristics of mathematics which make it an essential factor in the more advanced stages of the development of all other sciences. This may serve as a preliminary to an outline of the claims of mathematics to the attention of biologists, based on *a priori* considerations, on service in other natural sciences and on the contribution which it has already made to the advancement of biology.

I. THE FUNDAMENTAL CHARACTERISTICS OF MATHEMATICS AS RELATED TO THE PHYSICAL AND BIOLOGICAL SCIENCES

It is one of the characteristics of mathematics that, starting with certain axioms, postulates or assumptions, it shows the way in which conclusions may be deduced from these premises. The mathematician does not necessarily claim absolute certainty for the physical validity of his conclusions, but he believes profoundly that it is possible to find groups of axioms—sets of a few propositions each—such that the propositions of each set are compatible and that the propositions of each set imply other propositions, which latter can be deduced from the former with certainty. The assumptions of pure mathematics need have no physical interpretations. They may indeed contradict any of our theories. They must not, however, contradict each other. Thus it is the business of the pure mathematician to discover systems of self-consistent and coherent propositions.

Mathematics is an exact and final science only in the sense that with the postulates definitely given the conclusion admits of no doubt. Thus the pure mathematician concerns himself not with the solution of particular problems in the natural sciences but with the principles which underlie the solution of problems in general.

In the natural sciences, as contrasted with mathematics, the things which are given are measurements of natural phenomena rather than axioms or postulates. The scientist wishes to derive from these observational data generalizations which we call natural laws. It seems both reasonable and desirable that he should endeavor to employ in this task the rigorous self-consistent systems of reasoning developed by the mathematician.

The student of natural science need not necessarily concern himself with the criteria by which the mathematician assures himself of the validity of his formulae. He desires merely to be fully convinced of the usefulness of such formulae in the solution of the problems with which he himself has to deal. He should be sufficiently conversant with the fundamental assumptions underlying the equations which he proposes to use in his investigations, not to make the error of applying them in problems presenting wholly different sets of conditions from those for which they were developed.

The biologist in common with the student of the other natural sciences starts with a series of direct observations of phenomena. From these he wishes to derive a generalization, a theory or a law which shall express the results of his experience in concise and mentally comprehensible terms. A theory deduced from a given set of observational data may be erroneous because the measurements were made under unsuitable conditions, by inadequate methods, or because they are for some other reason unsuited for use as a basis of generalization. If the theories based on two or more sets of observations are inconsistent, the experimentalist refines the conditions under which his observations are made, increases the precision and number of his measurements and reformulates his theories until he finds one which is in accord with the widest possible range of experience and which appeals to him as a reasonable description of the facts of nature. Thus, were the mathematician to criticise the worker in the natural sciences, he would not require him to give up observation and experimentation but would only demand that the conclusions drawn from observation and measurement be logical conclusions.

II. The Claims of Mathematics to the Attention of Biologists

The claim of pure mathematics to the attention of scholarly mankind is like that of art, in that it is grounded in the innate human love of beautiful things and in the innate human joy in originating them. It is creative. Its previous triumphs of achievement fill us with satisfying wonder; its pursuit is akin to that of the exploration of a great mountain system in the course of which the vantage of each peak scaled opens to view the prospect of higher serried peaks and vaster plateaus beyond.

The pursuit of pure mathematics in our day by the few who have the ability and the training is not to be justified by the immediate applicability of its results in the other sciences. Its present existence is justified by centuries of persistent appeal to human interest. In no generation in which we would deem life worth while has such interest in mathematics been lacking. Thus its claim to the attention of the scholar has been tested by a rigorous natural selection. The survival of the science is sufficient evidence for its value as a source of gratification to the active human mind. Furthermore, the process of natural selection has not merely shown the fitness of pure mathematics as such for survival. It has been active within mathematics itself. All that has not been found to be sound and consistent has been ruthlessly eliminated. Thus all that has long remained may properly appeal to workers in the other sciences as worth their consideration with reference to its possible value in their own special field.

But here we are not concerned with the justification of pure mathematics, but with an appeal for the wider use of mathematics by biologists as a means to the development of their own special field of creative scholarship.

Let us consider in outline the claims which mathematics has to the attention of the working biologist.

The first two may be stated in very general terms. They will, however, be developed in the discussion of special claims which is to follow.

The most universal service of mathematics to the natural sciences is the affording of an exact and easily workable symbolism for the expression of ideas. The progress of science depends very largely upon the facility with which facts may be recorded and relationships between them considered. In their bearing upon this requirement of

the natural sciences it is important to note that an essential characteristic of mathematical methods is that they economize thought. The notation of the mathematician affords the maximum precision, simplicity and conciseness. The worker in natural science finds in mathematical literature a highly perfected symbolism which he may use without developing one of his own.

But while a convenient notation is the most general contribution of mathematics to the natural sciences, it is neither the only nor the most important one. In the natural sciences it is essential that accurate observations and exact measurements be interpreted by sound processes of reasoning. It seems logical to assume that the biologist may profit by the centuries of experience of the mathematician in the drawing of inevitable conclusions.

These claims are so general that we may properly turn to those based on the specific accomplishments of mathematics in the physical sciences and in biology itself in substantiation of our argument for its wider application in biological research.

(1) The Claim of Service in Other Physical Sciences

The record of service of mathematics in the physical sciences is an outstanding claim to the attention of biologists.

In the past, mathematics has been an integral part of the sciences which we are accustomed to regard as the more highly developed—of all that is physical as distinguished from biological in the growth of our civilization. The most determined critic of the application of the mathematical method in biology dares not contemplate the consequences of a Maxwellian demon snatching from our scientific literature and from the minds of our chemists, physicists, engineers and economists the mathematical formulae which underlie the routine of our daily life. In a few weeks long-distance communications would cease, the vehicles of transportation would be motionless, factories would close, and urban population would face starvation. As Professor A. Voss said in 1908, our entire present civilization, as far as it depends upon the intellectual penetration and utilization of nature, has its real foundation in the mathematical sciences.

If reasoning by analogy is ever justified, experience in the physical sciences would certainly seem to afford sufficient evidence of the necessity for the extensive introduction of this powerful tool of research into the biological sciences.

The argument that biologists should emulate the workers in the physical sciences is strengthened by the fact that biological phenomena are the most nearly infinitely complex of all natural phenomena. This is necessarily true because the internal structure and functioning of the organism and the effective environmental conditions under which it must live and reproduce comprehend a material fraction of the physical and chemical complexities of the universe. Before the more complicated biological phenomena can be grasped in any but the most circumscribed and superficial way by the human mind, they must either be analyzed and simplified by experimental control or expressed in the mentally intelligible terms of mathematical summaries or generalizations.

It may be urged that the method of dealing with large numbers of measurements is not that of the physicist or of the chemist who frequently works with minute samples under carefully controlled conditions.

The reasons for the differences in methods are two. First, the student of molecules has the advantage of working with less complex materials and under more readily controlled experimental

conditions. Second, the physicist or chemist already has his molecules or ions massed and can investigate them and draw conclusions concerning their properties from his examination of the properties of his volume of gas or solution. The biologist must begin otherwise. He must collect and determine the characteristics of each individual of a large sample in order to express the characteristics of the whole population in mathematical terms.

When biologists have had the necessary preliminary training, they will realize that, for many of the phenomena with which they have to deal, the most easily comprehensible and the most useful method of description and analysis is the mathematical.

In the past, biologists as a class have been in reality hostile to the introduction into their science of the methods which have proven their worth elsewhere. I know this to be true from long and bitter experience. Instead of being eager to place biology alongside of physics and chemistry in the ranks of the exact sciences, biologists have seemed not merely to excuse, but actually to take pride in the distinction which has been drawn between the so-called exact and so-called descriptive sciences.

While the historical attitude of the biologist is not excusable, the fault has not been entirely his. With most men mathematics is like a well—the deeper they go in the less they see out and about. Mathematics may quite properly be an end in itself, but in biology it is strictly a means to an end. While mathematicians have in the past been eager to serve workers in the physical sciences, and while mathematics itself owes a large debt to these sciences, mathematicians have not for the most part felt it worth while to come to the assistance of biologists. Mathematicians have often asserted the need of mathematics in the biological sciences, but the claim has too often been made in an *ex cathedra* manner by those who, while perhaps qualified to speak of things mathematical, have been relatively little fitted to discuss the needs of biology. While biologists have been entirely too slow in recognizing the needs of their science for the mathematical tools, they have shown that practical good sense which characterizes those whose minds have contact with matter by refusing to flock to the mathematicians' standard until shown by concrete examples that the mathematical method has real applicability in biology. Thus the burden of proof has largely been thrown upon a few workers of greater vision, with the inevitable result that progress in the application of mathematics in biology has been slow.

Progress has been slow, but progress there has nevertheless been.

(2) The Evolution of Biology and the Influence of Quantitative Methods

The natural sciences have had their beginnings in observation and speculation. Careful description of the observed phenomena then furnished a basis of interpretation by comparison. Experimentation, which requires not merely controlled conditions but measured consequences, followed observation and description. Finally quantitative measurement, calculation and the formulation of mathematical laws have characterized the highest stage of scientific development.

These stages in the development of the natural sciences are, to be sure, neither wholly distinct in nature nor sharply separated in time. The methods of the later stages have in some instances been anticipated by investigators who were in advance of their contemporaries. It would be unfortunate indeed if men of science did not at all times avail

themselves of whatever is best in the methods as well as in the results of those who preceded them. Notwithstanding the difficulty of delimiting the various horizons, as our geological friends might feel inclined to designate the deposits of scientific literature of these periods of differing dominant purposes, the sequence is in full accord with historical facts.

The old physicist who defined the biologist as "a man with scientific aspirations and inadequate mathematics" would find, if he looked over a fair sample of current biological literature, that not only has the space devoted to quantitative data increased enormously during the past few years, but that there is a steadily growing effort on the part of biologists to express in concise formulae the results of observation. Unfortunately biology in most of its phases still lacks the quantitative data and biologists in general want the training in mathematical analysis which is essential in exact science. Nevertheless the tendency of the times is unmistakable; the demand for quantitative work is more and more dominant in the biology of to-day.

The most forceful argument for the wider use of mathematics in biology is furnished by the service which mathematics has already rendered in the biological sciences. Let us consider this more specifically.

(3) The Two Fronts of the Advance of Mathematics into Biology

Progress in science depends upon evolution of method as well as upon the accumulation of the data of observation, experimentation and measurement. The progress which has been made in the development of biology as a quantitative science through the introduction of mathematical methods is in its present stage the resultant of various factors, which can only be understood when considered in their relation to the evolutionary history of science in general and of biology in particular.

This evolution of the natural sciences is admirably illustrated by the history of biology. Observations and speculations began with primitive man. If a desire to record what has been seen formed a part of the motives of those who bruised crude figures on the walls of caves, descriptions began with or before the period of written language. Some attempts at classification were made at a very early period in man's cultural development, but we are accustomed to think of the great era of description and classification as initiated in their modern form by the work of Linnaeus. This period was also one of detailed geographic exploration. Breadth of exploration doubtless tended to stimulate intensity of interest in description and classification. The activities of these decades resulted in the storing of great museums with carefully preserved and minutely described specimens of plants and animals, in the publication of elegant icones which are among the masterpieces of artistic bookmaking, comprehensive monographs of every large genus, encyclopedic summaries of phyla and kingdoms, and floras and faunas to the end of long vistas of library shelves.

Simultaneously with the latter decades of the period of description and classification of organisms, both living and fossil, began the development of anatomy and embryology, both macroscopic and microscopic. These latter were indefatigably pursued by an army of workers whose investigations were so comprehensive that the younger and more restless spirits began to fear that there would be no worlds left for them to conquer.

With such a wealth of descriptive materials at their disposal, it was inevitable that serious attempts at inter-

pretation should be made. Speculation as to the observed phenomena was largely replaced by effort at interpretation based upon comparison. "It is descriptive but not comparative," was the criticism of a volume laid before the elder Agassiz. The dominance of the comparative method over a considerable period of the more recent history of biology is attested by the presence of the word *comparative* in the titles of a number of institutions and journals.

With taxonomy, comparative anatomy and embryology, histology and cytology well outlined, biologists found themselves free to extend to other fields the methods which had heretofore been limited to physiology. Experimental morphology, experimental embryology and experimental evolution are terms which illustrate the degree to which the experimental method has dominated biological investigation during the last few years.

(a) *The Influence of Physics and Chemistry*

As soon as biology, in the course of its evolution, had passed the purely observational and descriptive stage and become an experimental science, it was natural that the attempt should be made to interpret biological phenomena in terms of the more highly developed sciences of physics and chemistry.

That many of the processes which occur in the living organism are chemical and physical in nature was necessarily admitted as soon as physiology could be called a science. The controversy between those who asserted that all biological phenomena are physical and chemical and those who maintained that living matter is in some essential way different from non-living matter has only served to stimulate investigations having to do with the physics and the chemistry of life processes.

The development of the field of physical and chemical physiology has been due not merely to its great theoretical interest but to its enormous practical importance in agriculture, in the industries and in medicine. At present biophysics and biochemistry have attained the rank of independent sciences, commanding facilities and personnel greater than that available for the whole of biology, with the exception of taxonomy, a few years ago.

The intimate contact with the more precise sciences of physics and chemistry which has resulted from the rapid development of experimentation in biology during the past few years has done much to raise the standard of biological research.

Physics and chemistry are not merely sciences characterized by measurement rather than observation. They are sciences in which it has long been recognized that progress depends upon the exactness of the control of the conditions of experimentation, the precision of the measurements, and the adequacy of the mathematical description and analysis of the measurements which have been made. Here we have one of the two great lines of advance of the mathematical method into the biological sciences. Physics and chemistry are quantitative and, to a high degree, mathematical sciences. Biologists, if they will pursue their science along the lines of physics and chemistry, must take over the mathematical methods of expression and analysis characteristic of these sciences. There can be no reasonable doubt that in the future physics and chemistry will continue to influence biology, and even more profoundly than in the past. As the association of these sciences becomes more intimate, and as the biologist becomes essentially a chemist or a physicist working with living organisms, the mathematical mode of description and analysis which have been so fruitful in physics and chemistry will become increasingly significant in biology.

(b) *The Rise of Biometry*

The penetration of the mathematical leaven into the biological lump through the medium of physics and chemistry has been so gradual and so little associated with the names of any individual workers that it has taken place without biologists as a class being acutely aware of the profound change in their science. The case is quite different with the second great line of advance of the mathematical methods into biology. This is directly traceable to the development, initiated by Francis Galton and strenuously carried forward by Karl Pearson, of mathematical formulae suitable for the analysis of the highly variable data of biological observation and measurement and to the application of these methods to a wide range of biological and sociological problems by the biometric school.

While the biometric methods were developed primarily for the study of phenomena which are so complex that they can not be grasped by the unaided human mind or which can not be readily subjected to experimental control, they are now being advantageously applied to the results of experimentation. Biologists will doubtless some day realize that experimental results must receive mathematical treatment for their full interpretation.

For the present, there are many who stubbornly refuse to see.

We are sometimes told that the biometric constants are merely a useful means of expressing results. The idleness of such an assertion will be apparent from two simple illustrations.

All mankind has had the opportunity of observing the statures and other physical characteristics of husbands and wives. Yet it remained for Pearson and his group to show that there is a high degree of assortative mating in man. Why was this not perceived if the correlation coefficient only serves to express what we may learn otherwise?

If the suggestion be made that those individuals who observed human husbands and wives were for the most part scientifically untrained, the reply is evident. Students by the thousands in the biological laboratories of the world have observed conjugation in Paramecium, but it required the biometric investigation by Pearl, working under the influence of Pearson, to show that in the union there is a high degree of similarity in the size of the conjugants. Even after the relationship was clearly demonstrated biometrically, its validity was denied by at least two eminent zoologists. If biometric methods are a useful means of expressing but not of obtaining results, why did not zoologists long ago note the assortative conjugation demonstrated by Pearl, and arrive at the explanations afforded by the masterly studies in the same field by Jennings?

The answer is obvious in both cases. Unaided observation was incapable of dealing with the problems. They required for their solution the application of mathematical methods of analysis to series of measurements.

These are by no means unique or exceptional cases. Instances of the failure of biologists to observe important relationships, even with the materials or the data before their eyes, could easily be multiplied. Examples of the misinterpretation of materials or data equally open to observation could be readily adduced. The mental limitations implied is not peculiar to biologists. The inability to grasp the more complicated natural phenomena without symbolism is an inherent limitation of the human mind, fully recognized by psychologists. That a man should be unable to reason about highly complicated phenomena without the use of mathematical formulae is no more remarkable than that he should be unable to see chromosomes without the microscope.

Another criticism frequently heard is that the statistical methods can only

locate problems—never solve them. The real solution, we are told, must in the end be biological, psychological, sociological, as the case may be. If this be true, it is the more important that the biologist, psychologist and sociologist be themselves capable of using the mathematical methods, or at least of cooperating intelligently with those who can. But is the criticism really valid? The same stricture is equally applicable to all methods of research. After a group of phenomena have been described and analyzed as well as they can be by any means, other problems remain to be attacked by new refinements of method or of analysis.

The assertion is often made that the final results must depend upon the original measurements and not upon their mathematical treatment. A full discussion of this criticism would lead into several complexities, but it is sufficient to answer by a very simple illustration. The possibility of securing accuracy beyond the power of observation, or at least beyond the degree of refinement of the measurements adopted, may be easily tested by measuring a series of objects twice, once roughly and once with great accuracy. The statistical constants of these two series of measurements may then be calculated and compared. Unless there has been a consistent bias or personal equation on the part of the observer which tends to make all his measurements too high or too low, there will be a remarkably close agreement between the results of the constants calculated from the gross and from the refined series of measurements.

Finally one of the most common criticisms of the biometric methods is that they are complex and difficult to use. We have been told seriously by biologists that they expect to adopt the biometric methods when they shall have been more simplified and hence made more suitable for practical use. But research does not tend to become simpler with the advance of science. Since biological phenomena are innately complex, there is no likelihood that the mathematical formulae required for their investigation will be simplified except in matters of practical technique. Criticism of the biometric methods on the ground of their difficulty is merely the glorification of the mental lassitude of the critic.

Let us turn from the answering of criticisms to things more constructive.

If science is to advance at the rate which we desire, another highly practical consideration can not be neglected. Many biological phenomena can not be subjected to experimental control. Thus while the proper study of mankind may be man, human individuals and their relatives can not be investigated in the same manner as white rats and Drosophila. While man may be the most conspicuous illustration of an organism which can not be studied in a broad way under controlled conditions, the example is not unique. In innumerable cases the statistical study of masses of data may not only properly, but must necessarily, replace controlled experimentation. I hope to show later that in such cases the experimental and the statistical method are in essence identical.

Even where refined experimentation is possible the biometric methods are particularly suited to reconnaissance work. In the search for the relationship between different variables the statistical analysis of large masses of comparatively rough data may indicate the place in which carefully controlled experiments may and should be made. Finally, after biological problems have been subjected to as close experimental control as possible, the results are generally so irregular as to make biometric analysis desirable.

Let us consider briefly, in review, the claims of the biometric methods to the attention of biologists.

First: The biometric notation makes possible the expression of the results of extensive experience in concise and mentally comprehensible terms.

This matter of the form of expression is one of far greater importance than might at first be realized. Rapidity of progress in any branch of science must depend very largely upon the facility with which the data and conclusions of a new investigation can be compared with those already on the library shelves. It is by the reoccurrence of like results that general theories are established. It is by the noting of inconsistencies and the circumstances under which they occur that indications of as yet unsuspected relationships are often seen.

There can be little doubt that the rapid advance of physics and chemistry has been due in no small degree to quantitative and standardized modes of expression.

If the physicist or chemist wants a solubility, melting point or conductivity of any substance, he has merely to turn to volumes of constants to find whether it has been determined, and if constants are available, whether the recorded results accord with his own. An investigator has been able to draw upon a common fund of knowledge to a greater extent and with greater ease than in biology. Thus synthetic work has been facilitated.

In its bearing on the problem of the simplification of scientific literature, consider for a moment the state in which biology would have been to-day had it not been for the Linnaean notation by which species may be designated by a simple binomial instead of by a cumbersome description whenever mentioned. The value of this relatively succinct notation becomes especially apparent when we contemplate the vast harm which has been done to scientific research through the unwillingness or inability of taxonomists to maintain uniformity of nomenclature. Then in view of what has been accomplished by this relatively simple expedient, imagine the rapidity of advance which will be possible when a quantitative mode of expression permits the results of many fields of biological research to be summarized in annual volumes of standard constants. I, personally, am inclined to look upon the publication of Donaldson's volume on the rat, in which the experience of a whole institution of workers is summarized in quantitative terms, as a real milestone in the progress of biology.

Second: The biometric formulae provide a system of probable errors which safeguards the worker in the formulation of his conclusions. Biometricians have referred so freely to probable errors that critics have facetiously suggested that biometry is chiefly error. But frankly and candidly, if a given set of observations are insufficient to demonstrate a relationship, is it not better that the investigator discover the fact himself rather than publish erroneous conclusions which must be corrected by subsequent research?

Third: The biometric methods furnish not merely a system of mentally comprehensible constants and concise equations, suitable for the description of complex phenomena, and a series of probable errors which safeguards the worker in drawing conclusions concerning these phenomena, but they make possible the investigation of relationships so intricate and so delicate that they are quite beyond the scope of unaided observation. Here the biometric methods have a potentiality for service analogous to that of the equipment of the modern observatory, which is capable of dealing with stellar phenomena that were beyond imagination a century ago or to that of modern microscopic equipment and technique which have given rise to whole sciences of microcosms which were beyond the ken of Linnaeus. To argue

that it is unnecessary to push on into the investigation of these more recondite relationships is as contrary to the spirit of science, as reactionary, as to argue that it were better to have stopped with Galileo instead of advancing to the refinements of modern astronomy through the development of instruments and mathematical theory.

Fourth: For many classes of problems the biometric formulae applied to large masses of data furnish the closest possible approximation to the experimental method of investigation.

The experimental method, as ideally applied, consists essentially in the simplification of conditions by rendering constant all but one. This one factor is then varied and its influence upon the organism is noted. In certain phases of statistical analysis an essentially identical method is followed, when we determine what is called the partial correlation between two variables for constant values of one, two or more other variables.

For example, the basal metabolism of tall men is on the average greater than that of those of less stature. Heavy men also show a higher daily gaseous exchange than light ones. But taller men are on the average heavier men, and it seems quite possible that the larger basal food requirements of taller men is merely the resultant of the relationship between stature and body weight on the one hand and between weight and metabolism on the other. The biometrician solves such a problem statistically by determining the partial correlation between stature and metabolism for constant weight, *i.e.*, with the influence of body weight eliminated. The experimentalist would have to attack the problem in exactly the same manner.

Illustrations might be given by the score of the analytical treatment of statistical data which gives results of essentially the same nature as those attained by the experimental method, often in cases in which strictly experimental technique can not be readily applied.

Fifth: The biometric formulae furnish the best means as yet available for predicting the value of one variable from another, or from a series of others. This is due to the fact that it is possible to pass at once from measures of interdependence in terms of the universally comparable scale of correlation to regression equations showing the rate of change in terms of the actual working scale of any variable associated with another, or others, whose values are known.

The great theoretical importance of this feature of the biometric methods will be realized when we remember that the test for the validity of a theory is its capacity for predicting the unknown.

The foregoing treatment in outline may have been disappointing to those who have expected argument by illustration of specific accomplishment. The method has been followed because the biological contributions which have already been made through the use of the biometric methods are now so large that no one man, even with unlimited space, can be expected to summarize them. This is true, notwithstanding the fact that the number of workers who have persistently stood by the biometric guns during the long and discouraging years of general biological indifference can be counted on the fingers without using all the digits of the hands.

III. The More General Service of Mathematics in Biology

It would be unfortunate to bring this paper to a close without emphasizing both certain limitations and certain wider services of mathematics to biology.

The biological universe is all but infinitely complex. It is not conceivable that all biological phenomena will be

treated by mathematical methods. All that is necessary, however, is that the mathematical methods of research be so developed that they may be applicable to any biological problem.

Nor must there be misunderstanding concerning the desirability of an unbroken front comprising all the methods of research in the attack on the complex problems of the biological universe. In biology evolution of scientific method has been of surpassing rapidity. Description was deserted when comparison became the order of the day. The mines of comparative morphology were in part abandoned when the cry was raised that experimentation was uncovering solid nuggets. The problems of biology are so numerous and so varied that no method of research can be permanently discarded. Observation can never fail to be the cornerstone of biology. The task of classification is only partly completed, even by those methods which were in use at the time when it was the major interest of naturalists. Taxonomy must profit by and ultimately incorporate all the pertinent facts unearthed by the newer methods of research. Comparison can never fail to yield results of importance. But all these methods may now be made more refined and exact by the introduction of mathematics applied to the description and analysis of quantitative data.

In closing, I would like to return to the broader subject of mathematics in biology and to emphasize two points.

My first point is in the nature of a prophecy.

In the future mathematics will have an increasing influence in determining the direction of research.

This is not due solely to the fact that the biometric formulae facilitate the solution of many problems but to the fact that after a certain stage in science is reached, calculation is to some degree capable of anticipating the results of experimentation. The value of the mathematician's prediction is well known to the physicist, chemist and astronomer. As yet little progress in this direction has been made in biology, but I am glad to go on record as predicting that before many years have passed experimentation will be to a considerable extent guided by preliminary calculation.

My second point has to deal with a very different matter.

Elegance or form has always made a powerful appeal to the mathematician. As the biologist is forced by the inevitable progress of his science to occupy himself more and more with mathematical literature, its logic, terseness and elegance of expression must have an influence upon his own standards of presentation.

Summarizing in a few sentences we may note that mathematics is driving into biology on two wide fronts.

On the one, physics and chemistry are by virtue of their influence upon biological research forcing biologists to take over the mathematics which is an indispensable part of these sciences. On the other, biometry is grappling with problems which are not readily amenable to experimental treatment.

The possible contributions of mathematics to biological science are too varied to be succinctly summarized. We must, however, record our entire disagreement with the dictum that mathematics is only a mill from which no more comes out than was originally put in. What is put in is raw data, the significance of which is obscured by all the perplexing irregularities due to morphological and physiological variation, to errors of random sampling and to errors of measurement. What comes out is a series of mathematical constants and equations, epitomizing in mentally intelligible form the whole discordant mass of irregularities and smoothing them in a manner to bring out the underlying

laws. To assert that the value of a biometric research is determined by the raw biological data is not altogether unlike measuring the value of a Titian by the grams of paint required to cover the canvas.

It has been the rare good fortune of Quetelet, Galton and Pearson to initiate one of the great lines of advance in biology. These men will one day receive from biologists recognition as free and generous as their great service merits. As for the rest of that little handful of workers who have made up the biometric school, it has been the satisfaction of a few never to have stepped back from the guns during the long and discouraging years of biological indifference and opposition.

The ultimate recognition of mathematical biology is merely a part of that inevitable and irreversible evolutionary process by which biology is to take its place in the ranks of the exact sciences.

AMERICAN OVER-SEAS CARRYING TRADE

By Professor EZRA BOWEN
LAFAYETTE COLLEGE

More than half the ships entering ports of the United States in 1790 were American. Only England offered serious competition.[1] Just before the Civil War, the tonnage of the United States, including ships engaged in domestic commerce, was not far from one third the total tonnage of the world; Great Britain accounted for another third; the tonnage of all other countries, taken together, scarcely surpassed the American. The merchant fleets of the United States exceeded by half the number necessary for the carriage of exports and imports.[2] A poor, new country, during the first seventy years of its life, held a leading position among seafaring nations. But a startling decline occurred in the next half century. Just before the World War, the overseas shipping of the United States had shrunk to a scant one million tons—compared with England's eighteen million tons![3]

During the World War the tonnage of the United States engaged in foreign trade increased enormously. A scant million tons in 1913 became nearly two and one half million in 1917, and by 1921 the forced draught of wartime construction, continuing into the post-war years, had produced a total tonnage engaged in foreign trade of more than eleven million.[4] But this great expansion was purely an artificial growth produced at great expense. At Hog Island, the largest of the war plants, the cost of construction varied from month to month between $125 a ton and $200 a ton for the hull and a similar amount for the machinery. At the same time ships were being built on the River Clyde at a cost which amounted to one half or one third of the American figures. After 1920 this war-tonnage went rapidly out of use, and, in spite of the activities of the U. S. Shipping Board, the tonnage of ships built and documented in the United States appears to have returned to prewar levels.[5]

The point of greatest interest, however, in this brief recital of the history of the foreign-going[6] merchant marine of the United States is the spectacular success achieved in the years which lie between the founding of the nation and the Civil War and the even more striking decline in per capita overseas tonnage between the Civil War and the Great War.

What causes lie behind a nation's gaining a leading position in the carrying trade, and then suffering a complete collapse—all within little more than a century? What do the historians say? The almost rank growth of the early American overseas carrying trade is explained in terms of ready cargoes, excellent harbors and abundant shipbuilding materials. These are strong and self-evident points of argument, but their strength melts instantly when one recalls that they lost entirely their effectiveness after the sixties of the past century. If harbors, cargoes and shipbuilding materials include all of the causes of the early rise of American shipping, it is necessary in explaining its subsequent decline to show that one or more of those factors disappeared—a stiff task. Good harbors remained, and

[1] Johnson, Emory R., (and others) "History of Domestic and Foreign Commerce of the United States," Vol. ii, p. 11.

[2] Day, Clive, "History of Commerce," 1922, p. 526.

[3] The Statesman's Year-Book. 1926.

[4] Lloyd's Register of Shipping, 1925.

[5] "Statistical Abstract of the United States," 1926.

[6] The lake, river and coastwise trade is reserved by law to ships of American registry—it is a domestic monopoly.

few would agree that cargoes were less abundant. It does appear, however, that radical changes in ship construction came with the decline in tonnage which it is so hard to explain. Ships of metal began slowly to take the place of wooden vessels. Steam instead of sails became the propelling force. But the United States was as rich in coal and steel and engineering skill as ever she was in wood or in the art of sailmakers. High wages drove American ships from the ocean.[7] True enough, but what made wages high?[8] Other explanations are offered for the sharp decline in foreign-going tonnage following the Civil War: Steel and steam becoming established in shipping while America was in the throes of civil war—or recovering from the effect—England took advantage of her diversion and won a lead which it was impossible for Americans to overcome.[9] This argument loses force, however, when one recalls that Japan's merchant marine was developed almost entirely in the past fifty years—establishing clearly that a time handicap, however great, is not fatal when conditions fundamental to the growth of a merchant marine are present. A collateral explanation of the almost total disappearance of the American flag from the high seas, after the Civil War, is that privateers flying the Confederate flag destroyed so great a proportion of the American tonnage that her citizens could not make good the loss.[10] But this explanation seems to assume that the ratio of loss to total was greater than the proportion of British ships which fell victims to German submarines and cruisers during the World *War; for that loss was completely recovered, and no one pretends that it had any permanent effect upon the prestige of British shipping. The war loss of Great* Britain was 7,379,986 tons—more than the entire merchant fleets of any *two* other nations.[11] No; we must look elsewhere for an adequate explanation of both the rise and fall of the American overseas shipping business—and a criterion for judging its future trend.

Most commonplace things are inconspicuous. A well-known trick of the mind relegates them to oblivion. In this way it has been generally overlooked that man is not a marine animal. Man is content to remain ashore so long as he can find a living there. Nations do not develop an overseas carrying trade until they are forced to. Flying fish learned flying to save their lives. Bats developed wings and took to the air by necessity. Whales, which the biologist tells us are mammals and by nature land animals, went down to the sea in droves only under compulsion. Men went down to the sea in ships only when they could not make a living upon dry land. We offer as a hypothesis of the development of an overseas carrying trade the proposition that nations do not develop merchant fleets until other opportunities for livelihood have become overcrowded. Let us see how far it goes toward explaining the rise and decline of the merchant marine of the United States.

In its early years the United States was a poor, slight nation.[12] Thirteen miserably endowed agricultural states, strung loosely along fifteen hundred miles of coast line, the western part of many of them was little better than wilderness.[13] With land transportation what it was in that day, these states appeared to be hopelessly hemmed in between the sea and the great Appalachian

[7] Oberholtzer, E. P., "A History of the United States since the Civil War," p. 214.

[8] It was mainly the opening of the West that ran up wages—and furnishes the pivot (see below) of our theory of the decline of American shipping. Both are the result of one change, the opening of the vast new economic opportunities.

[9] *Cf.* Oberholtzer, E. P., "A History of the United States since the Civil War," p. 214, *ff.*

[10] Day, Clive, "A History of Commerce," p. 558.

[11] Fayle, C. E., "The War and the Shipping Industry," p. 418.

[12] "Cambridge Modern History," Vol. 7, The United States, pp. 305–688.

[13] McMaster, John Bach, "A History of the People of the United States," Vol. 1, p. 3.

barrier. The center of population was twenty-three miles *east* of the city of Baltimore.[14] As late as 1800 there were only six "cities" with a population of more than eight thousand inhabitants.[15] In contrast with the present, it was estimated that nine tenths of the people were farmers. Even in New England, where such meager industries as existed were centered, only one eighth of the people were employed in manufacture, trade and pursuits other than agriculture.[16] Even agriculture was badly carried out and the yield was often slight. Washington wrote to an English agriculturist: "The English farmer must have a very indifferent opinion of our American soil when he hears that an acre of it produces no more than eight to ten bushels of wheat; but he must not forget that in our country where land is cheap and labor is dear, the people prefer cultivating much to cultivating well." Clive Day says of manufacturers in the United States at this time that only one—the manufacture of rum—was strong enough to produce a considerable surplus for sale outside of the country, and that all manufactories were of a simple character requiring no great technical skill or elaborate machinery.[17] Roads, which furnished the only means of communication and transportation by land, were the dirt roads of the colonial period, thick with dust in summer and sloughs of mud a foot or more deep during the thaws of winter and spring.[18] Wagons were nearly everywhere a rarity. Sledges were used on the farm. Persons and products moved from point to point on horseback. There was so little intercourse between the adjoining towns of East Hampton and North Hampton, on Long Island, that each town preserved peculiarities in pronunciation down to the year 1800.[19]

During the colonial period (the effect extended well into the federal period) manufacture was further discouraged by English legislation. The exportation of manufactures was restricted; the importation of machinery was prohibited; trade even among the colonies was curbed.[20] Early mills in New England were built from smuggled plans or from the memory of some skilled Manchester immigrant—even the emigration of skilled workers was prohibited by England.[21]

One industry, however, shipbuilding, was encouraged by British legislation.[22] The colonies supplied not only their own need for ships but sold them abroad. Before the Revolution more than a third of the British tonnage, it was said, was American built.[23] In Massachusetts towns, a ship could be built of oak for \$24 a ton, while in England, France or the Netherlands an oak vessel cost \$50 to \$60 a ton.[24] Even fir vessels, built on the Baltic, inferior in strength and durability, cost \$35 a ton.[25]

Here then we have a nation of poor farming states, strung loosely along the Atlantic coast line, hemmed in between sea and mountains[26]—in fine, situated

[14] Reuter, E. B., "Population Problems," p. 19.

[15] Reuter, *op. cit.*, p. 36.

[16] Day, C., "History of Commerce," p. 472.

[17] A slight oversight appears here. Further on Day calls attention to the fact that one third of the British merchant tonnage was American built. Here certainly was a "considerable surplus" sold outside the country—in the manufacture of ships.

[18] MacGill, E. C. (and others), "History of Transportation in the United States before 1860," pp. 54–60.

[19] Day, *op. cit.*, p. 486.

[20] Bogart, E. L., "Economic History of the United States," pp. 43–4.

[21] Bogart, *op. cit.*, pp. 134–136.

[22] Clark, V. S., "History of Manufactures in the United States, 1607–1860," p. 18.

[23] Fiske, John, "The Critical Period of American History," p. 137.

[24] Bogart, *op. cit.*, p. 52.

[25] Day, C., "History of Commerce," p. 495.

[26] MacGill, C. E. (and others), "History of Transportation in the United States before 1860," pp. 3–4; also "Cambridge Modern History," Vol. 7, pp. 53–5. Fear, especially of savage Indians, added to the effect of the mountain barrier in confining people to the coast. See Marvin, W. L., "The American Merchant Marine," p. 1.

geographically and economically much as the ancient Phoenicians on the western shore of the Mediterranean and the modern Norwegians, and, like the men of those two most intensely seafaring nations, early Americans went to sea, not because it was "in their blood," but because there was little else for them to do—save difficult farming.[27] They built up a merchant marine which rivaled Great Britain's—then as now, the largest in the world. The American flag was seen beside the British in every port. . . . Came a great change, this weak, loose-knit string of states became in a short space of time a broad empire: the Appalachian barrier was punctured—the most important event in American history after the Federal Constitution.[28]

Turnpikes and canals were the early outlets or punctures: The Cumberland Road, the first public improvement undertaken by the federal government; the Wilderness Road; the famous Erie Canal, which made New York the commercial center of the nation, and the Delaware and Chesapeake Canal. The Cumberland Road, opened in 1818, was a great national enterprise; the Wilderness Road was mainly what constant travel made it.[29] The first boat passed through the Erie Canal in 1825.[30] Then came the railroads—though the great east-and-west lines were not completed until after the Civil War. Railroads finished, in effect, the flattening out of the barrier which stood between the poverty stricken United States of Washington's day and its richly abundant future, which in the whirligig of time became the background of an unexampled economic power. Railroads made the west completely available.[31]

So formidable did the Appalachian divide appear to the eyes of "the fathers" that sober men, Washington[32] and Jefferson[33]—and later so keen an economist, statesman and business man as Richard Cobden[34]—saw the probability of the weak young nation's breaking its back upon this rude barrier and becoming two separate nations, one erected on either side of the mountains. The establishing of a western empire with himself upon the "throne of the Montezumas" and annexing all territory west of the Alleghenies, it will be recalled, was the foundation of Aaron Burr's treason.[35] The hopes and fears of these men are our warrant for saying that the puncturing of the Appalachian barrier was the most important event in American history after the Federal Constitution. Its effect on shipping was exactly what our hypothesis would lead us to expect. People lost interest in the sea and turned landward to feast their eyes upon a treasure house of economic opportunities, open and at hand.[36]

Why should youth, during the sixties and seventies of the last century contemplate the sea when railways opened to view and grasp almost limitless fields of opportunity: the wheat fields of Nebraska, Kansas and the Dakotas, the oil fields of western Pennsylvania, Ohio and later, of the Southwest, the corn fields of Iowa, Illinois, Indiana and Ohio; the cotton fields of the East-South-Central

[27] It is noteworthy, though the point should receive thorough investigation before it is taken fully into account, that in Virginia where farms were rich and broad, there were few home-owned ships, save bay and river craft or fishermen.

[28] *Cf.* "Cambridge Modern History," Vol. 7, "The United States," pp. 687–696.

[29] MacGill, E. E. (and staff), "History of Transportation in the United States before 1860," p. 7.

[30] Cowdrick, E. S., "Industrial History of the United States," p. 118.

[31] "Cambridge Modern History," pp. 694, Vol. 7.

[32] Fiske, John, "The Critical Period of American History," pp. 212–3.

[33] Morse, John T., Jr., "Thomas Jefferson," Chap. xiv.

[34] Cf. Morley, John, "The Life of Richard Cobden," Chap. iii.

[35] Morse, John T., Jr., "Thomas Jefferson," p. 249.

[36] Lord Acton, "Lectures on Modern History," p. 307.

States; then there were gold fields and silver fields, copper fields and vast reaches of timber. Youth in America no longer looked seaward, but went west.

The westward movement of population was under way as early as 1815. There was a light trickle of population over the mountains from the beginning; nevertheless, the American overseas carrying trade continued to grow until 1860. But with the exception of the "gold rush" of 1849, there was no nation-wide appreciation of westward opportunities until, or after, Greeley's day, the sixties and seventies of the past century.

The hands of engineering genius, which broke down the Appalachian barrier, destroyed also America's merchant marine—by destroying the key incentive to the development of an overseas carrying trade, *a scarcity of other economic opportunities.* Engineers opened the way for the development of natural resources and a great industrial economy. Before the progressive process, which we have called the puncturing of the Appalachians, began—a process initiated by the opening of the Cumberland Road and completed by the final consolidation of east-west lines of railway—the United States had the second largest merchant marine in the world, a carrying trade grotesquely out of proportion to economic development in other directions. After the flattening of the Appalachian barrier, and just before the World War, the American flag had almost disappeared from the high seas. It was represented by a scant million tons of shipping.[37] Had overseas shipping continued to develop even as fast as foreign trade (imports plus exports), the United States should have to-day a merchant fleet of twenty-six million tons.[38]

[37] "Statistical Abstract of U. S.," 1926.

[38] Foreign trade (exports plus imports) in 1913 amounted to ($4,278,000,000) twenty-six times as great as in 1800 ($162,000,000) when the American merchant tonnage was just short of one million.

What then of the future? Prophecy is always dangerous and often profitless. But prediction is the purpose of all science. The chemist studies molecules and atoms, their qualities and behavior, so that he may predict what will happen when they are thrown together in certain proportions. The physicist studies force and matter that he may predict the consequence of a certain application of force to matter. The sociologist, the economist and other social scientists study human interplay so that they may predict how men and their social contrivances will react in their various relationships. Only by prophecy, then, can we escape the charge of futility.

If we apply the hypothesis that a nation develops a notable overseas carrying trade only when opportunities for economic activity are wanting or have become exhausted, it seems patent that if the United States is to acquire a merchant marine to match economic development in other directions, the process will be a slow one—or an artificial, stimulated growth.[39]

Though outlets for economic activity in the United States are far from being exhausted, the first cream has been skimmed, and the second skimming is in process of collection. This exhaustion, or preemption, of economic opportunities forms the foundation of a present growing interest in overseas shipping—an interest which in the nineties of the past century even Senator Hanna, with his singular political power and enormous business prestige, was unable to stir up.[40] Americans of the second quarter of the twentieth century are beginning to look seaward; and it is conceivable that a nation which in its infancy competed for shipping primacy may in the full strength of maturity compete again.

[39] Presidents Harding and Coolidge, shrewd judges of the drift of public sentiment, both favored the granting of ship subsidies.

[40] Croly, Herbert, "Marcus Alonzo Hanna," Chap. xxii.

SELECTION AS A FACTOR IN HUMAN EVOLUTION

By RALPH E. DANFORTH
CHESTERFIELD, MASSACHUSETTS

SELECTION is here used in a very broad sense. Millions of words have been written on natural selection since Charles Darwin's time, and to these mountains of literature nothing need here be added save the conviction that natural selection of some sort was among the instrumentalities used in making man what he is. In spite of changed conditions it will always have to be taken more or less into account in the changes yet to be wrought in man and his world.

We are just arriving on the threshold of selection in its comprehensive and most useful form. It is only as man trains his selective faculties more highly and learns to use them more constantly and in all the multifarious departments of his personality and his environment that his evolution can continue to its logical perfection.

The wizardry of artificial selection in the making and improvement of our splendid domestic animals, fruits, vegetables, grains and flowers is one of the most fascinating themes, one of which we never tire, yet it can never be fully told, for much of its most thrilling portion is in the unrecorded past. In honor to this great agency, through which we possess the foods on which we depend each meal of each day of our lives, every one with a garden should consecrate a few more moments to the selection of seeds, and therefore to the study of his individual plants to select the seeds from the most vigorous, disease-resistant, most productive and, above all, those of distinguished quality. A very few seasons of such selection yield most pleasing improvements, the plants also becoming better adapted to your local conditions through the generations. Personally I grow all my own garden seed, and count that the most interesting part of my garden work.

Natural selection and artificial selection possessing such vast and unique powers, we must realize that in the selective principle, taken as a whole, lie untold possibilities, of which we have only observed a little, and whose rich storehouse of treasures we have only begun to mine.

During many ages a wise man now and then has suggested the value of selecting the thoughts that we think. To-day some suggest that we should rigidly select and reject in the matter of reading. Occasionally we even hear of a person who deliberately selects the environment in which he cares to live, and who then steadily tries to change it to make it fit his ideal even more closely. In fact, the difference between the exceptional person and the average person to-day lies in whether he takes his thoughts as they come, his surroundings as he finds them, and acts in the ways requiring the least thought or selection; or whether he is esthetic and enterprising in these matters.

Energy must be spent in living, whether we will or no; why not then spend it walking the most beautiful paths to a definite goal, instead of continually wallowing to get out of pitfalls? Selection, or the lack of it, will make all the difference. Just as one example of this, one man sees much of the race burdened with excessive sex impulses; he blames the Puritans for it, and says it is a reaction from their teachings; when, if he had read more intimately in the literature of the past, he would see beyond all doubt that the race has always been thus burdened since the beginning of history; and if on top of this he would

study the whole world of living things, comparing the one species, man, with all the other species of animals and plants, he would be led to the inference that the race had been thus burdened in prehistoric times, ever since the beginnings of leisure and the unwise selections in the use of leisure.

Increased leisure doubtless came to man when, through his increasing intelligence, his food supplies were increased, stored and otherwise made more dependable.

The happiest use of leisure remains one of our major problems. Maybe it will never be well solved by or for the masses. It may often be erroneously solved by upper classes. One who knew well what is in man said that many travel the way to destruction, but few the way to life. The few do some selecting, the many do not.

The solution of one's leisure problem depends on the training and experience of his selective faculty. The same is true of his problems of work.

By the method of "trial and error" the one-celled protozoan, like the average man, flounders around in a hit-or-miss fashion.

The exceptional man selects his thoughts and his acts and thereby builds for himself a fortune, a garden or an education. One person has a fine character: it was made by judicious selection. The old book of Deuteronomy tells us that life and good and death and evil are spread out before us, and counsels man to choose life, that both he and his seed may live. Selection, and unrelenting selection, each day and at every turn in life, is a part of the price one must pay to live well.

Keen perceptions, good powers of observation, clear vision, both physical and mental, seem essential to judicious selection. Unfortunately not every one is naturally gifted in these respects. This doubtless is responsible, in part, for the scarcity of those who exercise selection. The present, the near and remote future loom bright to those thus gifted. Some even possess such clearness of perception, such almost unerring accuracy as to savor of the spiritual, of something, like starlight or sunlight, from above our ordinary horizon.

Genius strikes our race in many surprising forms. The well-rounded man should be a genius in every trait which possesses lasting worth. The future evolution of man must produce some ideal human beings. Elimination will doubtless be very effective in raising the general level. The elimination, in some way or other, of the many who have eyes but will not see, and ears but will not hear—who will neither perceive nor select aright in the important things of life—is both scriptural and highly scientific. In the improvement of men or fruits or flowers by selection, the very best are considered, the rest are disregarded. But it is all too easy to err in such discriminations. The neglected stone or the lost sheep may prove truly superior, and at the same time prove how defective is our judgment in these matters. Yet there can be no doubt that there are countless human dogs that never appreciate things choice or holy, and human swine who would but trample on the rarest pearls of thought or action and do injury to those offering them the opportunities.

The human tree which can not by its intrinsic nature bear good fruit is hewn down. Pruning, fertilizing, educating and moral suasion can not, we are told, do the trick, in many cases. To avoid the possibility of wronging any through errors of judgment, the whole human race should be given opportunities to show what they are, and what they may become under favorable circumstances. But this very act will require forceful restraint of hordes of vicious, bad folk whose deeds, and whose very existence are so wicked as to prevent the fair treatment of the worthy. Far more

human souls have been hurt by the wicked than by errors in judgment of the well-meaning.

Selection of environmental factors is of tremendous importance in the continued evolution of man. Selection of hereditary characters is, of course, more fundamental, but the environment is often all too potent in repressing the best traits, or rendering impossible the exercise of choice gifts. The very best surroundings possible can be none too good for the development of the ideally gifted man. There is an old saying; the greater the man the greater his temptations; so that I fancy that such superior beings as may be developed in future will have enough to try them, enough to develop their characters, even in the best of environments.

Our surroundings in this world can hardly be too carefully selected, too comfortable, too healthful, too beautiful, too inspiring. Even when the ideal in these matters has been approximated, the greater constructive tasks, which shall by then have arisen, will be enough to tax to the utmost the larger powers of the men and women of the time. Such times will not be dull and monotonous, as some are wont to predict, but will be beyond our present power to conceive in interest, in difficulty and in rewards. Alarmists have always abounded to warn of the dangers of the great waves or milestones in human progress. Many were those who predicted evil from the widespread introduction of machinery and inventions and discoveries. Numberless scholars in past times have conscientiously opposed the education of the masses.

Our civilization is advancing to greater heights at a speed unknown in former times. This is due to greater concentration and larger cooperation along constructive and scientific lines. In these constructive enterprises the demand for really first-class men is more than double the supply. The rapid improvement of our environment requires a greater supply of such superior personalities; therefore, in order to effect this greatly desired improvement in our environment we must find a way to raise the caliber and increase the number of truly first-class people. The work can not be done rapidly and efficiently without them. We are all convinced that our surrounding conditions of life must be improved. We sometimes even find a person who finds fault with other *folk*. Something or somebody must be improved. The development and improvement of our constructive and scientific civilization, therefore, is one of our most visible motives for selecting more and better organizers, creative workers, scientific thinkers, inventors, seers.

True progress, however, exists for man, rather than man for progress. At our present stage of development, however, it is easier for most people to realize the need of improving our surroundings than to see the need of changing man himself. This does not matter as much as might seem to some, for both the improved environment and the improved race are absolutely necessary, and the one can not be had without the other. Try as hard as we may to improve our surroundings, we are up against a blank wall, so far as really lasting improvements go, unless we also improve the improvers. Many of our fondest educational schemes have proved but empty bubbles. Hundreds of brains have toiled for years over social and political panaceas which have but crumbled to ashes. No amount of digging and educating, fertilizing and training, cultivating or pruning will make a valuable and fruitful orchard if the trees in it are intrinsically or innately inferior or mediocre. We can not get good fruit from bad trees nor good results from inferior people. There is no educational nor political panacea to fit their case.

A corrupt society, a mistaken, hazy, superstitious and erroneous atmosphere

will always surround foolish or semi-foolish people. This hazy mental atmosphere not only surrounds such social groups, it emanates from them. It is a natural by-product of their mental metabolism. All of us, unfortunately, have some of their blood in our veins; while the average man has far too high a percentage of it.

It can hardly be said that there are any human thoroughbreds; even the best and smartest families on earth have made too many errors of judgment in their matings. In searching their ancestry they do not have to search far before running across some careless, impulsive matrimonial blunder, and an ancestor has been added to the line who brings more of burden than uplift to his or her descendants for indefinite generations, until, by chance, the genes are so divided up that some descendant, more fortunate than the rest, may fail to get one or more of the undesirable hereditary traits. But he is equally liable to fail to get some of the best traits.

We will have to grade up from the best "grades" we have, in our effort to produce more intelligent, more beautiful, more disease-resistant, more altogether superior human beings. What better can we do if there are no true thoroughbreds? Is it *possible?*

Fortunately, some of us wholeheartedly believe in a great personality who created all the heredity scheme, and everything else in the universe. We believe this all-perfect and all-powerful Being can make possible to those who believe, and who add to their faith works —(to the utmost of human knowledge and power)—many things which might otherwise be impossible without such faith and knowledge and works. If we do not use what brains and what science we now possess toward making better brains in the future and better science, we may expect to have what brains we have and what knowledge we possess taken away—like the one talent hid in a napkin—and our opportunities given to those more worthy and more gifted than ourselves.

Could it be possible, we repeat, by judicious selection on the part of the best human "grades" to grade-up, and eventually to produce real thoroughbreds? For answer take a look at what has been done in flowers, fruits, animals and grain, starting only with wild grasses, wild beasts and weeds.

But there has been much selection, painstaking selection, even indefatigable study of the organisms in the process, leaving no trait unobserved, unsought or ill-considered. So it must be with the human pedigree. Most patient selection, and—far more rejection.

In this matter of selection there are certain relations between pedigree and performance which are very simple and yet ignored entirely by many. Individual traits and individual performance are well worth considering. No fine person could wish to marry any one who was not entrancingly lovable, of fine appearance, strong, highly intellectual, clean physically and mentally and morally, full of life and fascinatingly interesting. Such a person would never care to marry a paper pedigree, but would require to fall in love with a real person whose individual personality and individual performance excited admiration and inspired love. But such a superior individual is pretty sure to be the product of many fine ancestors whose individual performance records average very high. Very well; let this pedigree be studied with painstaking care and patience, and if it be so proved, then to one's personal estimate of the lovable individual is also added a substantial guarantee that in this individual is a solid, substantial worth that will show itself both through the years that are ahead and through the ages yet to come, a foundation of lasting worth on which may be built yet fairer mansions for the souls of future men

who will look back to you, their forebears, and truly honor their fathers and their mothers, that their days may be long in the glorious land which the Lord their God is to give them.

Performance to-day is pedigree of tomorrow. This is one of the simple relationships between pedigree and performance. Your performance to-day actually becomes part of your offspring's pedigree. Your individual performance record is a very substantial part of your individuality. It is very largely what you will be judged by by your great-great-grandchildren. The great-great-grandchildren of others will look it up in estimating your descendants. This will be done far more in the very near future than it is being done now. It is a part of the rapidly growing scientific lore of to-day which will become a part of the *life* of to-morrow. Many new things which we barely reach toward to-day will become deeply ingrained in the life of to-morrow. As tomatoes and oranges but a short time ago were tasted sparingly by a few of our forebears, but to-day are part of our substantial diet, and as electricity, steam, gas-engines and airplanes come rapidly into integral relationship with former essentials of the foundations of our life, so also will many other ideas and practices which to-day seem a bit hazy to some, or entirely beyond us to others.

So that even though the ancestry of a high-grade human being of to-day may not be altogether to his liking, let him remember that so far as he or she individually is concerned he can make his own personal part of his children's pedigree very excellent. This he will do by an individual performance record of the highest order both in what it omits and what it includes. He will sedulously omit everything from his life and even from his thoughts which a far more scrupulous generation than our own might take exception to. He will include daily deeds of such nobility and worth to his generation as to raise him greatly in the esteem of God and man. He will add, to the utmost of his ability, to his education, to his physical strength and health and appearance, to his material wealth as so much added power for good, to his success in business, in his profession, or as a statesman, to his capacity for service both to man and to the Kingdom of God —in short, to his whole physical, mental and spiritual make-up. With this lofty individual performance record ever as his aim he will go forward and upward along the path of life more joyously and more richly than his less gifted companions who may be plodding along more selfishly and without the forward look into the better ages yet to come.

Selection demands our attention at every turn. Selection in the important things, selection in the little things, selection every moment of life. As the wild song-bird must keep its eye ever open for a hundred creatures of the earth and air that are ready to do it harm, and at the same time seeks most skilfully for food for itself and for its young, and also rejoices with full heart in all the beauties of nature around it, so man has to select and to reject or avoid, in little things and in the most important, in his daily and hourly habits and in the supreme and unique crises which may come but once in a lifetime. Woe betide the luckless one who on an impulse enters blindly the great crisis of life and throws away his birthright.

Foolish also is that man or woman who, either before or after the great event of marriage, squanders wastefully the sublime energies of life's sacred fires. Biological science of to-day reveals the greatness and sublimity of these vast reproductive forces. Such a trifler brings to life's sacred altar but the fag end of a worn-out potential parent, and too often deprives his offspring of the choicest free-gifts of the universe, gifts which no after education or wealth or food or medicine or travel can ever re-

place. The big deception of it all is that persons think they are marvelously enriching their lives by what really robs them of life's hidden wealth. Some of the biggest lies are ever being sown the world around by people who *ought* to know better, and by some who *do* know better but delight to deceive themselves and others. Selection will deal roughly with all such—some day, "if not before."

Happy the person who from infancy begins to select beautiful interests—flowers and birds, mossy rocks and sunny fields, butterflies and crystals, mountains and stars, poetry and music! Twice happy the child who, in addition to these wholesome, growth-giving environmental factors, comes up also in an atmosphere of *stimulating* religion! Whatever may be said in favor of the various great religions of the world, there seems to be but one that offers incentive to personal development, physical, mental and spiritual, along most wholesome, natural lines, to a goal of absolute perfection and divine completeness and power and righteousness, peace and joy. Other religions may have their excellent points, or the reverse, but no other furnishes the incentive and stimulus to the highest endeavors and attainments foreshadowed in the dominant religion of the leading civilizations of the most scientific and progressive portion of the human race to-day.

The child brought up in an abundance of pure air, with much outdoor life and direct sunshine, plenty of fruit, vegetables and milk all through the year, with steadily growing interests in nature, and living in a home atmosphere of the highest mental and spiritual stimuli, will early have his selective faculties developed and strengthened.

By constant daily use the selective gift may grow, under the best guidance, to a point of unerring accuracy almost uncanny, almost supernatural. On reaching youth, and later on reaching maturity of full manhood and womanhood, people thus fortunately conditioned would choose, as by second nature if not truly by first nature, those interests and occupations, those companions and thoughts, those places of amusement and exercise, and finally those professions and life-partners which would be alike most beneficial to themselves and to the world. They would naturally shrink or recoil from all destructive or wasteful thoughts, practices and associations, be repelled by vicious factors and foolish impulses from within or suggestions from without. The unsavory would escape them. Gloom, despondency and weakness would have no part in their personality. As individuals, their life curves, correctly plotted, would soon turn up toward the infinite zenith. As families, through the generations, progressive improvement toward a race or group of ideal people in beauty and perfection of body and also of mental and spiritual endowments and activities would be theirs.

It is wise selection which makes one man rich, while the lack of it finds another man poor; one man strong, while another is weak; one man radiantly joyous, while another is sad.

Each individual, in selecting constantly and continuously the elements which make up his environment, association or companionship, and the stimuli of his thoughts, may make the most or the worst of what his ancestors have passed on to him as the result of their mate-selection in the past. The same individual, by judicious mate-selection, may pass on to his children improved, or at least unimpaired, the gifts of his ancestors. He may thereafter by wise selection surround those children with an approximately ideal environment—with the aid of a well-chosen mother for the children. If then the judicious choice is repeated or improved upon through the succession of generations, making use not only of individual judgment, taste,

etc., but also of pedigree and other records, the good traits will be strengthened and increased in number, while bad or weak traits, resulting from careless or uninformed mate-selections in the past, may in time be practically bred out from the stock.

I would not be misunderstood as claiming that an individual's performance-record can be inherited by his children. Neither can his good environment benefit them directly unless they also share it or a better one which may be the logical outgrowth of it. But I do claim that an individual's performance-record becomes his personal contribution to his pedigree, and is valued by his descendants and their relatives according to its quality, as indicating what his inherent qualities were capable of performing and indicating also that these same capacities may be coursing in their own blood or imprinted in their protoplasm, either diluted or reinforced. In this respect personal performance is of far more value to students of heredity than some have realized. As a true index of the possibilities lying within the hereditary qualities of an individual, what could be better than the accurate record of his performance? And this performance may be developed to its highest and finest possible or may be neglected or even largely ignored by the individual throughout his whole life. I am personally acquainted with some men of unusually fine mentality, men who also possess sufficient health and strength to back up their minds in great achievements, yet who are spending their whole lives as nonentities. Such bright men can not help knowing that they are peculiarly gifted. Two of them admit frankly that they are too lazy to achieve anything great. The others fall back on that worn-out and insufficient excuse that they had had very little schooling. That, of course, is arguing in circles. Schooling can be got by those who have the mind and the will, or it may be given to oneself, for there is no schooling like that which comes of itself along with actual achievement of a high order. Not only hundreds but thousands of men have demonstrated that they could fairly devour knowledge which they most needed right in the course of a very busy life of achievement.

There is no excuse for allowing any good hereditary gift to lie unused or only half developed. He who practices well the faculty of selection which I am advocating will search thoroughly his own physical, mental and spiritual make-up to see if there is not some good quality or possibility within him which he may have overlooked in former similar surveys. Here also he will be aided by research into his pedigree, or the performance of his ancestors, which may call his attention to inherited characters within himself. This may show him a reflection of himself from a new angle. At the least he will be honoring his father and mother by taking the pains to find out about them, and about their fathers and mothers, as far back as faithful search can reveal anything. It is a respect which everybody owes his forebears. Let it not be put off, then, with that trite and flippant excuse for human indolence, "Oh, I am not at all interested in genealogy."

But the things which by wise selection one *omits* from his life are nearly as important as those he *includes*. Sometimes they are fully as important as the inclusions. Certain poor or worthless elements, habits or thoughts may, if included, actually inhibit or repress valuable elements, habits or thoughts. Those who have their selective faculties highly trained through constant practice find that in order to develop certain valuable elements in their complex to their highest degree it is positively essential to drive out or to smother other elements.

Viscount Rothermere, one of the world's greatest newspaper men to-day, and Mussolini, one of the world's greatest organizers to-day, have each pulled

out two threads from the fabric of their lives, as indicated by Rothermere's account in the London *Daily Mail,* and reported by the New York *Herald Tribune.* While in Rome Rothermere visited his friend Mussolini. In his account he comments upon Mussolini's executive capacity and memory. He then says: "Strict self-control and economy of time are the secrets by which this high standard of efficiency is achieved. . . . He sleeps eight hours a night. For ten years he has not taken a drop of alcohol. He does not smoke. He regards alcohol and tobacco as entirely unsuitable for people who have hard mental work to do." Rothermere then adds: "His opinion confirms my own experience and practice, for out of regard to the heavy responsibilities resting on me I have been for some time past a teetotaler and a non-smoker."

These and other omissions on the part of the selectively trained, for the sake of high achievement and great efficiency, may prove to be the negative concomitants of the positive virtues they so highly prize. The really electric, vital man who *does things* requires both positive and negative electrodes. The nonentities neither positively develop anything in their lives nor negatively repress anything. They do no selecting. All nature cries "Select!" but they growl, "What's the use?"

"Marry in haste and repent at leisure" is a motto voiced by many throats daily, in one part of the world or another. It is the belated awakening of a bit of the selective faculty.

"Love is blind," some say, but with eyes wide open during the love-making, and the mind doing some scientific investigation of the ancestral history of the parties concerned, the love may be truer, deeper and more enduring.

We are immeasurably indebted to hundreds of unknown benefactors who have selected and produced many cereals, fruits and vegetables on which we now depend. This work was done partly by our own ancestors, partly by natives of various lands. For example, we owe to pre-Columbian natives of the Andes such valuable staples as the potato, sweet potato, peanut and tomato, and the size and some other valuable qualities of our cultivated strawberries. Our own ancestors had been cultivating very small and soft berries prior to crossing these with the large, firm berries cultivated by natives of Chile.

The same scientific, selective process which we employ in educating our minds, building gardens of lovely environment around us, choosing ideal climates, filling our hearts with joy and beauty in place of haphazard commonplaceness and developing fine fruits and other foods from wild plants of field and forest—this same judicious selection applied to our own species has power to improve us physically, mentally and spiritually, and render us capable of selecting our environment and our flowers, vegetables, grain, sugar cane, rubber trees, livestock, fruits and mates even more wisely in future than our race has done these in the past. We can hardly start training our esthetic faculties of discrimination in all things too young. This is general selection. Natural selection, like wild fruits, nuts and roots, is good in its place; we may never know how much we are indebted to it; but voluntary, intelligent selection in all things which may add to the value of life is incomparably better for us from now on.

GREENNESS AND VITAMIN A IN PLANT TISSUE

By Professors JOHN W. CRIST and MARIE DYE
MICHIGAN STATE COLLEGE OF AGRICULTURE AND APPLIED SCIENCE

THE term "vitamins" is comparatively new in the vocabulary of science and in common parlance. The use of this term has become surprisingly universal in an amazingly short time. At the thought or mention of it a sense of mystery and wonder creeps in, and such common commodities as cod-liver oil, yeast, milk, oranges and carrots arise into consciousness as lowly things of vast consequence. However, though we have coined and popularized the term, are using it to name an elusive something which seems to be present in certain food products, and are profiting from an increased use of these products, our generation can not claim the distinction of having first learned that there are certain edibles in nature which have a peculiar function in the promotion of human growth, health, strength and longevity. History often serves as a curb which is effective in the discipline of modesty. Green plants, most of which are classified as vegetables, have served the race a good while, and, what is more, have long been recognized as having nutritional virtues exceeding those to be expected on the basis of their ordinary chemical composition.

In ancient Rome there was a great naturalist who wrote some valuable works on plant life. His name was Pliny. In one of his books is to be found the following story. The Emperor Augustus was dangerously ill. His death seemed certain. Lettuce as human food was in existence at that time. In fact, lettuce as a salad plant seems to have been raised as far back as we have any authentic history of mankind. It was served at the tables of the Royal Palace of Persia in the sixth century B. C. and was present in China in and probably before the fifth century A. D. Well, Augustus had a craving for lettuce, but his physician would not prescribe it for him. In that case, he adopted a common American custom, namely, dismissed the doctor and retained another, whose name was Antonius Musa. This physician, being more intelligent or else more cunning, immediately prescribed lettuce. The emperor ate it with abandon and promptly recovered. The commons of Rome showed appreciation by erecting a statue to the physician in one of the public squares of the city. This happening gave such publicity to the lettuce plant that it was made a part of the diet of the people everywhere in the nation. They used a substance called "oxymel" to preserve lettuce that they might have it at all times of the year. The preserved product was known as "Meconia" and was nearly as potent as the fresh material. Pliny remarked of his own accord that the lettuce of the day contained an abundance of soporiferous milk, was somewhat blackish in color, had a cooling nature and that in the summer it was very grateful to the stomach, freeing it from nauseation and giving a good appetite.

The disease known as "scurvy" was the main causal factor leading to the trial and use of vegetable products as specifics for disease. While scurvy is related to Vitamin "C" rather than "A," some incidents from its history will serve to draw attention to the fact that long ago the general and also more or less particular value of fresh green vegetables was recognized.

No history of medicine could be complete nor even acceptable if the name of John Huxham (1692–1768) were omitted. In his famous "Essay on Fevers" he differentiated typhus from typhoid fever. He was the man who prepared tincture of cinchona bark. His "Essay on Antimony" is a classic. Strange as it may seem, when, in 1747, twelve hundred of the seamen of Admiral Martin's English fleet were down and disabled with scurvy, Huxham recommended that they be put upon a fresh vegetable diet. His prescription was a success.

The value of fresh vegetables for seamen became more and more evident to other physicians of the times, notably James Lind (1716–1794). Lind was surgeon in the Royal Navy (1739–1748). He is referred to as "the Founder of Navy Hygiene" and as the "Father of Nautical Medicine." Something had to be done, for scurvy was putting the English navy out of commission. Lind saved the day by his insistence upon the seamen being fed citrus fruit juices and fresh vegetables. Largely through his influence the English government was finally led to officially include these items of daily diet in the ration of the navy.

Below is given an extract from the personal memoirs (Vol. 1) of General Philip H. Sheridan, U. S. A. It is an episode from his life while he was stationed at Fort Duncan, Texas, in 1854. Speaking of this experience in the southwest the famous spokesman for the words, "Turn, boys, turn, we're going back," says:

> During this period our food was principally the soldier's ration; flour, pickled pork, nasty bacon—cured in the dust of ground charcoal—and fresh beef, of which we had a plentiful supply supplemented with game of various kinds. The sugar, coffee, and smaller parts of the ration were good, but we had no vegetables, and the few jars of preserves and some few vegetables kept by the sutler were too expensive to be indulged in. So during all the period I lived at Fort Duncan and its sub-camps, nearly sixteen months, fresh vegetables were practically unobtainable. To prevent scurvy we used the juice of the maguey plant, called pulque, and to obtain a supply of this anti-scorbutic I was often detailed to march the company out about 40 miles, cut the plant, load up two or three wagons with the stalks, and carry them to camp. Here the juice was extracted by a rude press, and put in bottles until it fermented and became worse in odor than sulphurreted hydrogen. At reveille roll-call every morning this fermented liquor was dealt out to the company, and as it was my duty, in my capacity of subaltern, to attend these roll-calls and see that the men took their ration of pulque, I always began the duty by drinking a cup of the repulsive stuff myself. Though hard to swallow its well-known specific qualities in the prevention and cure of scurvy were familiar to all, so every man in the command gulped down his share notwithstanding its vile taste and odor.

These and other early and even ancient observations on the singularity of certain plants as possessors of a something that is very essential to the normality of the human organism are very interesting. Remembering, though, that human creatures in general have always had "the will to live," have always insisted on living the longest possible time and have ever sought desperately to remain in the best of health while living, we should not be surprised at what history reveals. It could hardly be expected that the race should have failed until now to stumble onto parts of the vegetable kingdom as sources of prevention and cure for some of the dreaded ills that have ever been in close pursuit, threatening to extinguish the species entirely. The crude yet quite effective method of "trial and error" was in operation long before the dawn of what we are pleased to term "The Scientific Era."

Not until the latter part of the nineteenth century did real scientific inquiry into this fascinating question begin. The splendid investigations of Eijkman (1897) pioneered the way. These were

followed by the works of Hopkins (1906) and those of Holst and Froelich (1907–1912). The theory of vitamins or the necessity of one or more unidentified accessory factors (present in certain edible materials) for normal nutrition was originated, and as a theory has held the field against all others that have been proposed. And, at the present time, though we do not know exactly what any one of the several vitamins (A, B, C, etc.) is, either chemically or physically, the evidence at hand is sufficient to make their reality seem overwhelmingly probable. We believe in them hypothetically.

For the purpose of the present article the so-called Vitamin A may be selected out for special attention. It is referred to usually as the growth vitamin. In general, though not in particular, the definition is correct. On diets deficient in Vitamin A the expert diagnostician notes several symptoms of disorder in the animal organism, while the outstanding, summarized, clearly visible consequence is the lack of growth and even sharp losses in weight. Death may result if the deficiency of the vitamin is extreme and continuous for a relatively long period of time. Its significance is great enough to cause serious concern regarding its location in nature.

Fresh vegetables constitute one of nature's richest storehouses for Vitamin A. This fact has been adequately proved and now the recommendation of fresh vegetables for the diet of the human being, especially when still undergoing growth, is made universally in all civilized countries. This is well and good, but it should be emphasized that species of vegetables are quite numerous, that they vary considerably in Vitamin A content, and, furthermore, that there are many ways of preparing these products for the market, for preservation and for being served at the dining-table. Celery is offered to the consumer in the bleached state; lettuce as green leaf lettuce and also as head lettuce, where the greater part of the head is only slightly green to entirely non-green; tomato fruits as they come ripe from the plant and again after having been picked green and ripened artificially with some sort of heat or gas treatment; asparagus is sold either fresh or in cans in both the green and the bleached state. These conditions have raised a number of questions, among which is that of the relative merit of a vegetable when bleached as compared with its value when green. Undoubtedly, the bleached product often looks more attractive, is more succulent and brittle, has a nicer taste, is more suitable for some of the fancy notions of the chef, and, on the whole, serves the aristocratic ambitions of the persons concerned more efficiently. But, does it have equal quality as a nutrient material? All evidence obtained thus far goes to show that the green product is far superior to the non-green.

Experiments conducted in England have shown that the inner whitish leaves of the cabbage head are very poor in Vitamin A, while the outer green leaves are rich in this respect. Through other experiments it has been demonstrated that the stalks of bleached celery contain no more than traces of Vitamin A. This vitamin is also deficient in the inner leaves (the bulk of the head) of head lettuce, and in the innermost yellowish leaves is probably entirely lacking. At Michigan State College we have conducted some experiments wherein the Vitamin A value of green and bleached asparagus in the diet of white rats has been determined. The results have not been published in technical form as yet, but were reported at the meeting of the American Association for the Advancement of Science held at Nashville, Tennessee, in December, 1927. These experiments demonstrated that when growing asparagus is covered over in the row

with soil and the tips cut before they reach the surface and become green by exposure to the sunlight, their value in terms of Vitamin A is very low indeed. Animals fed on the fresh white tips lost weight, became badly diseased and died before the end of the sixth week, while other animals receiving an equal amount of fresh green tips were healthy, vigorous and gained weight at the rate of about five grams each per week. Approximately the same result obtained with other groups of animals where the two kinds of tips were cooked before being fed. In still other lots of animals canned green and canned white tips were fed, the daily amount of the white being double that of the green. The increased quantity of the bleached did not suffice to give growth or even prevent death, while the animals on the canned green tips grew in normal fashion.

Clearly, it seems that there is some connection between greenness in the foliar tissue of vegetable plants and their content of Vitamin A. Just what the nature of this association may be is as yet an unsolved problem. Scientists wonder if the green pigment or some part of its chemical make-up is itself the vitamin, or if the presence of the pigment is essential to the synthesis of the vitamin in the tissues of the plant, or if the pigment is merely coincidental as a side development in those conditions of environment in which the plant manufactures the vitamin. Their wonder is leading them to erect hypotheses and to perform laborious experimentation in an effort to unravel the mystery. True enough, in a few cases animals have been made to grow when fed seedlings which had grown under conditions that prevented their becoming green, but it required daily quantities of the material which were many times greater than necessary of green seedlings. And furthermore, there is the possibility that the potentially green pigment bodies are present in such tissues in a colorless elementary state. In time, the deeper secrets will be revealed. Modern biological research is very aggressive and has already made a record that justifies confidence in its future.

At the present time, though much has been accomplished, it must be said that as regards the question of almost any one of the several vitamins perhaps only the threshold of inquiry and discovery has been crossed. Further progress in the task of revealing the nature of the relationship between greenness of plant parts and their Vitamin A quality will hinge in part, perhaps in the main, on fundamental research with the green pigment itself, which is known to the botanist and chemist as "chlorophyll." A good deal is already known about it, but all this is probably meager compared to what is not known and should be learned. It is made up of carbon, hydrogen, oxygen, nitrogen and magnesium in the general proportion of $C_{55}H_{72}O_6N_4Mg$. The structure of the molecule is very complex and need not be discussed here. It exists in the normal green leaf in at least two slightly different forms or varieties which are not exactly the same in either structure or proportion of chemical elements. Basically, it is an organic acid of the tricarboxylic type combined with two alcohols (methyl or wood alcohol and phytol alcohol). Due to this fact, it is classed as an "ester" and belongs in that great general group of compounds which contains, roughly, such familiar things as butter, tallow, olive oil, beeswax and most of the artificially manufactured fruit essences. Generally speaking, chlorophyll does not form in the leaf in the dark and is less in plants heavily shaded while growing. It does not form unless iron be present in the plant cell and carbon dioxide in the atmosphere surrounding the plant. Plant parts without chlorophyll are incapable of

manufacturing the sugars that are synthesized in these parts when they are green and exposed to light. Though leaves contain sufficient chlorophyll they do not function in food manufacture unless they are exposed to light. In some mysterious way chlorophyll manages to capture, transform and render available the energy contained in rays of light. All this seems like a good deal to know. But really, it may be a mere beginning of knowledge. Why are these things so? How do they come about? If chlorophyll in either an elementary or finished form is indispensable to the production of Vitamin A in plants, we as yet have hardly the slightest inkling as to just what the subtle connection and process is in its details. Once such information has been mined and systematized the synthesis of the vitamin in the laboratory may be possible and its function and employment in the diet of human beings be rendered more intelligent.

In the meantime, while we wait upon science, it is well to eat fresh vegetables and still better to prefer that these be decidedly green in color, when it is the foliar part of the plant which is used. That last clause is inserted lest it be forgotten that with a good many vegetables the edible portions are not foliar in character and are not green. Examples of this are the fleshy roots of the carrot, the beet and the radish. Are these to be excluded because they are yellow, red and white rather than green? Certainly not, for experiments have shown that they contain the vitamin factors. They were produced as parts of plants whose tops were green. The food substances they contain were built up in these tops and transported to the roots for storage, and likewise the vitamins that are known to be there. Milk, butter, cheese and other food products coming from domestic animals are not green and yet they afford Vitamin A. The answer is apparent when it is recalled that these are herbivorous animals in part or entirely. The amount of Vitamin A in cow's milk and consequently in the butter made from this milk varies with changes in the pasturage or the plant roughage furnished for the cows.

This article should not be concluded without the addition of two or three paragraphs that are somewhat critical in nature.

Scientific discoveries usually arrive at the stage of completion by slow degrees. Oftentimes, as in the case of the vitamins, long before investigation has been concluded the discovery becomes known to and is appropriated by the public. Frequently the new thing creates more or less of a sensation. It is adopted at once and in a manner more or less fanatical. We may, in our great enthusiasm, run past the limits set by the lack of more complete experimentation and understanding. When so, we take the risk of useless worries and costly mistakes. Many who have insisted prematurely on the X-rays, radium emanations and ultra-violet light have had no benefits or else got burned by "playing with the fire." The point is that even though fresh green vegetables have been proved to be rich in Vitamin A, and some of the other vitamins as well, it is unwise to become so excited about it that we overdo the eating of them, in the sense of throwing the diet out of balance. Food products other than green vegetables afford Vitamin A and are imperative for certain additional properties not common to green vegetables. Every vitamin is essential, but the foods containing it are required for other reasons as well. Because of this there must be a variety with the several individual items therein properly selected and correctly proportioned. This having been accomplished, the all-important vitamins, as best we know now, take up as a part of their duty the task of acting as stimulators which serve to facilitate and regulate

the biological processes in which the foods that afford energy and give tissue building material are digested, absorbed, distributed and assimilated.

Secondly, it is apparent that there is a tendency to misjudge the relationship of vitamins to nutritional disorders. No doubt vitamin deficiencies are responsible for a great many of the troubles which human beings experience, but not all, for it should be remembered that there are at least some major and minor disturbances and irregularities with which vitamins may have little or nothing to do. Vitamins are not magic cure-alls for any and every sort of ailment that can occur. The need for expert diagnosis and treatment of nutritional troubles is not less but greater perhaps than ever before. Multiplied remedies demand increased knowledge and wiser prescription. As the last sentence in his book on "Scurvy" Dr. Hess used the following: "There is a growing danger of attributing every unexplained nutritional disorder to the new, overworked but ill-defined vitamins—of their sharing with the secretions of the endocrine glands the fate of becoming the dumping-ground for every unidentified disorder." While progress in an understanding of the vitamins and their rôles in human nutrition has been made since this book was printed, the danger to which the author alluded has not disappeared. Ideal advancement is that type which is mixed with a degree of conservatism that is sufficient to make changes in practice wait upon the presentation of incontrovertible evidence of fact.

MALARIA AS A FACTOR IN ITALIAN ENVIRONMENT

By Professor W. O. BLANCHARD

UNIVERSITY OF ILLINOIS

ITALY has long been the classic land of malaria. From whence it came or when introduced is not known, but that it was well established in the Peninsula long before the Christian era is certain. For at least twenty-five centuries it has taken a heavy annual toll of life,[1] and the economic loss through decreased efficiency of labor and reduced utilization of areas subject to the disease have been enormous.[2] Even to-day one third of the total area and 40 per cent. of the population of the entire Kingdom are in communes officially "malarial." The number actually living in the infected *parts* of such communes is about 12 per cent. of that of Italy or about four million people. The number of cases "officially reported" annually runs over two hundred thousand and it has directly or indirectly affected the social and economic welfare of the whole population.

In the centuries following its introduction into Italy devastating wars, both civil and foreign, by discouraging agriculture and especially by their destruction of the irrigation and drainage systems, caused much of the cultivated land to revert to pasture and marsh, thus providing favorable conditions for the spread of malaria. Extensive deforestation by aggravating the flood problem added to the difficulties. It is well known that certain sections of south Italy which, in the eighth century, were sites of large and prosperous communities have since been rendered desolate and barren by the ravages of malaria. The increase in the area affected in the southern part of the Peninsula since 1860 has been extraordinarily rapid. In 1880 only six of the sixty-nine provinces of Italy were entirely free from the disease; in 1885 there were only two; in 1902–5 there were eleven and in 1923, seventeen.

The close connection between malaria and marshes was early recognized; indeed, long before the relation of the disease to the mosquito was known. The name itself (mal-bad; aria-air) owes its origin to the common belief that the foul air from swamps carried the infection. Naturally the first measure of protection undertaken involved the drainage or filling in of overflow lands or, failing in this, the abandonment of the vicinity as a human habitation, at least during the summer season. At this time of the year drought turns many streams into chains of stagnant pools which with the high temperatures then prevailing, provide the optimum conditions for mosquito breeding.

REMEDIAL MEASURES

The reclamation of poorly drained land has always been in Italy one of the two most important lines of attack on the malarial problem. When Italy became a united Kingdom in 1870 there were over four and one half million acres of land with drainage so bad as to be a menace to health. A vigorous cam-

[1] However, the death-rate in recent years from measles, from typhoid or from tuberculosis is larger than that from malaria. The mortality from tuberculosis in 1923 was over sixteen times that from malaria.

[2] It has been suggested as an important contributing factor in the national decadence of Spain and in the fall of Greece and Rome. See Regnault, Dr. Felix, "The Rôle of Depopulation, Deforestation and Malaria in the Decadence of Certain Nations," Annual Report, Smithsonian Institution, 1914, pp. 593–7.

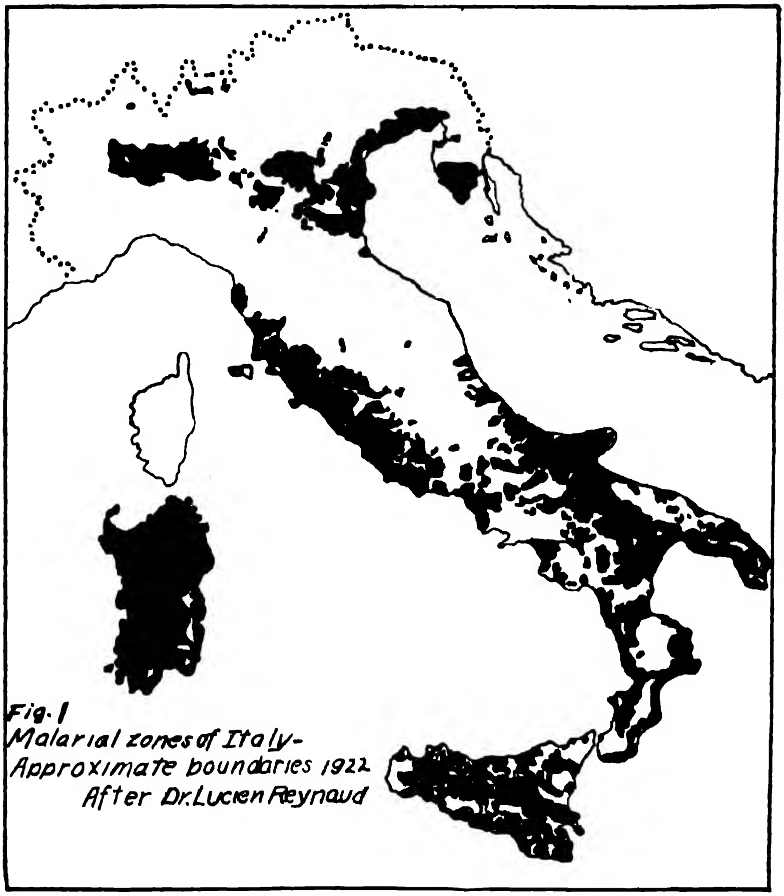


Fig. 1
Malarial zones of Italy-
Approximate boundaries 1922
After Dr. Lucien Reynaud

paign of state reclamation begun in 1880 has to date restored to use about one half of this acreage. Of the total which required improvement over three fifths was in north Italy, although the warmer central and southern parts of the Peninsula and the islands have always been the worst infected with malaria. Agricultural development has quickly followed the completion of the government drainage projects in the north; in the central and south it has lagged. The reclamation work has not only reduced the breeding of anopheles, but by improving living standards it has increased the physical well-being and resistance of the people to malarial attack.

A second and no less effective measure in the antimalarial campaign has been to make quinine, the principal specific, available to all. Though the virtues of this drug had been known since the seventeenth century it was not until the government took over its manufacture and distribution as a state monopoly in 1902 that it was placed within the reach of even the poorest peasant. Its distribution free or at small cost has been a tremendous boon to rural Italy, and the enforcement of the "quinine laws" has been marked by sharp declines in the malarial death-rate.

The real modern antimalarial campaign in Italy dates from the beginning of the present century. The discovery

of the rôle played by the anopheles mosquito as the transmitter of the malarial parasite gave a tremendous impetus to the fight, and high hopes were entertained for the speedy elimination of the disease. Needless to say, they have failed of realization. True, the discovery placed additional weapons at the disposal of the campaigners. The oiling of stagnant waters, the introduction of mosquito-eating fish, the screening of dwellings, all came to be a part, though a minor part, of the campaign. The major credit for the reduction of the malarial menace still rests upon the drainage and quinine measures.

The Campagna

The work of "bonification" or improvement, by which the malarial districts are being gradually reclaimed may be illustrated by the Roman Campagna, for centuries one of the most notorious of malarial districts.

The Campagna is a vast plain about the capital city, underlain by impervious clays. The soil is fertile, the climate good and the presence of an excellent market in the capital seemed to furnish all the requisite conditions for a prosperous agricultural region. Indeed, in ancient times, this section supported a dense population, but for centuries it has been desolate and all but forsaken.[3] Less than 10 per cent. has been under cultivation. Without forest, towns or permanent homes it has been inhabited in winter by scattered herdsmen, but even these retreated with their charges to the mountains in summer. For the past half century the government has repeatedly tried to colonize the region but until recently with little success. Of late the prospects have been more promising. In addition to general reclamation works and quinine legislation various economic inducements have been included, *e.g.*, the building of roads, introduction of electric power, extension of long-time loans to settlers, exemption of buildings from taxation and the providing of agricultural experts as teachers. From 1900 to 1906 the proportion of the inhabitants affected by malaria was reduced from 32 per cent. to 4 per cent. and the agricultural revival is changing the whole appearance of the Campagna (see Fig. 2).

Fig 2. Cases of malaria in the Roman Campagna and Pontine Marshes After Dr Lucien Reynaud

Distribution

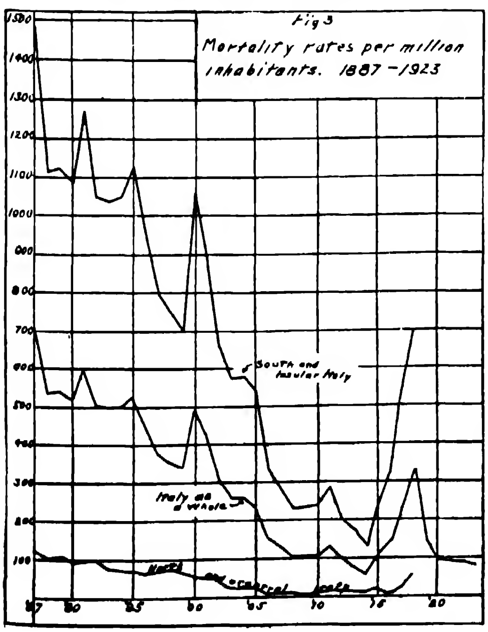
The distribution map of malarial zones (Fig. 1) shows a striking resemblance to the physical map. The dependence of the disease upon the anopheles mosquito as the carrier naturally confines it largely to the plains region, where favorable conditions for the propagation of mosquitoes exist. This is especially unfortunate for Italy, since with a dense population still chiefly agricultural it needs every acre of soil available for food production, doubly so since the area of lowland is so limited. It is estimated that for Italy as a whole only one fifth of the surface is plains, the remainder being equally divided between mountain and hill land. Assuming that the mountain areas are free from malaria, this means that more than one half of the plains and hills, the most productive of Italy's lands, are malarial zones.

In north Italy the Po valley and north Adriatic coast, in central Italy, the low-lying coastal plains, are favorable malarial areas. The mountain streams, checked in their descent from Alps and

[3] Depopulation that set in with the fall of the Empire apparently reached its lowest stage in the seventeenth and eighteenth and first half of the nineteenth centuries. Ashby, T., "The Roman Campagna in Classical Times," London, 1927.

Apennines, deposit their silt, clog up their lower courses and provide extensive overflow lands. Dunes aid in lagoon formation along the coast, and even in the hill and mountain country open quarries and crater lakes have been prolific centers of infection. In south Italy and on the islands the infected area includes considerable upland as well as the valleys and coastal plains. Here the higher temperatures and more marked seasonal irregularity of the river region are more favorable for mosquito breeding. It is in this southern portion of Italy that the disease carries with it a large proportion of fatalities, while in the north it is very mild. Thus, Basilicata in the extreme south had from 1901 to 1905 an average malarial death-rate in proportion to the number of inhabitants, fifty times that of Lombardy in the north. Malaria may well be charged with a considerable share of the responsibility for the retarded development of this southern part of the peninsula and the island.

Figure 3 shows the decline in death-rate. The decrease is most striking.



Thus from 1887 to 1902, the period preceding the quinine legislation, the mortality averaged fifteen thousand annually; from 1903 to 1905, with the enforcement of the malarial laws, the average fell to about one half that figure. Fluctuations are of course to be expected, partly in response to climatic differences, partly as a result of human activities. The latest recrudescence, it will be noted, came during the war period when the exposure of vast numbers of men and their movements from place to place were bound to spread the disease. In addition war activities not only interrupted the antimalarial campaign but actually destroyed vast irrigation and drainage systems, thus releasing the check upon mosquito breeding.

The number of deaths is of course only a part—and but a small part—of the total loss and suffering caused. From 1919 to 1923, inclusive, there were officially reported an average of fifty-six cases of illness for every death. How many malarial attacks were never officially reported is, of course, unknown, but the number must have been large. A disease so common and one in which the standard specific—quinine—may be administered by any one, together with the fact that many of those affected live in isolated sections would indicate that the numbers officially reported are far under the real figures.[4] Professor B. Goss estimates that the average annual death-rate of fifteen thousand from malaria between 1903 and 1905 represented some two million cases, or a ratio of one death to one hundred and thirty-three attacks.

In addition to the marked success of the antimalarial measures in saving life there have been notable economic results. The national government spent in the

[4] Malarial illness began to be officially reported in 1902. After reaching a high point of 323,000 in 1905 they declined and in recent years have usually been less than 250,000.

work from 1900 to 1920 about $100,000,000. The improved land has an estimated value of $400,000,000. It is of course recognized that the accomplishment in stamping out the disease has not been everywhere satisfactory or commensurate with the cost.

The most common effect of malarial infestation has of course been depopulation and the reversion of land to waste or to pastoral use. This change in the type of land utilization has resulted in a modification of agricultural methods, of land ownership, of population distribution and of emigration. For example, since the anopheles works at night and chiefly in summer, the agriculturist must spend that part of the day or season in the hills. This has favored the grouping of the population into towns in the uplands, rather than in scattered rural homes on the cultivated land. Thus in south Italy where malaria is at its worst, though a non-industrial region, the percentage of the inhabitants in towns is greater than in the industrial north. As a consequence of such an arrangement much labor is lost through the workers having to walk long distances to and from their fields. Intensive agriculture, favored by a dense population, is correspondingly handicapped. Latifundia and absentee landlordism have been fostered and a strong impetus given to the emigration of the hungry population to more favored lands. Thus, though primarily a rural or agricultural problem, its effects are directly or indirectly felt throughout the whole social and economic scheme.

THE BIO-ECOLOGY OF FOREST AND RANGE

By WALTER P. TAYLOR and W. G. McGINNIES

THERE are some 470,000,000 acres of forest land and some 1,055,000,000 acres of range and pasture land left in the United States. Attempts to develop agriculture on cut-over coniferous forest lands in the Southwest have usually failed. Likewise, attempts to use the semi-arid range lands for dry-farming have not been successful. Such facts indicate that these areas probably are filling their highest use as producers of timber, forage, and associated wild life. Unless our systems of farming make unprecedented changes they should always remain as forest and range.

Our forests are being depleted at least four times as fast as timber is being grown. In spite of the prevalent use of brick, metal, concrete and other wood substitutes to-day, the demand for wood and wood products is as insistent as ever. Nor is there any likelihood that it will fall off in the future. Regularly recurrent drought years emphasize the inadequacy of the forage resource. The specter of overgrazing threatens live-stock production on the western ranges. At the same time the need for meat and meat products is increasing. The value of these commodities certainly makes them deserving of scientific attention.

On critical examination, almost every outstanding problem concerned with the relation of organisms to environment is seen to have a biotic setting. Under natural conditions, a study of vegetation alone or animal life alone lacks completeness. Neither one by itself makes up an independent unit. The basic unit is the biome and its physical environment. Thus we find that forest and range research entails a rather comprehensive study of all forms of organic life together in their inorganic surroundings.

Clements (MS) has said: "All of the biological processes of the community are expressed in (1) response to the habitat, (2) reactions upon it, (3) coactions between the members of it." Researches on response to habitat and of plant reactions on habitat are numerous. Reactions on habitat by animals have received little attention. Some studies of interactions or coactions between plants and animals, animals and plants, animals and animals, and plants and plants, have been made, but it is believed that augmented attention will produce much valuable information.

The significance of bio-ecology to the problems of forest and range lies in the fact that the grazing of domestic stock, wild game and grass and browse-feeding rodents is often a dominant factor in the environment. The degree of grazing may in a large way determine the character and amount of vegetation present. In the forest and range environments, available moisture is often the greatest single factor operating to limit or promote vegetative growth. Close cropping reduces the moisture available for plant growth by increasing losses of water by run-off, percolation and probably evaporation. The effects of this partial desiccation are cumulative and in a few years may entirely change the character of the environment. Furthermore, the influence of grazing conditions on the headwaters may radically change environmental conditions many miles away by causing streams to dry up or floods to sweep through the valleys.

In Arizona and New Mexico, there is one of the largest continuous forests of western yellow pine in the country. In certain localities the burning or reckless cutting of this timber have had serious and far-reaching effects. Physical and

biotic factors of site have been modified to such an extent that recovery will be slow, if, indeed, it takes place at all. Overstocking the yellow pine type with sheep and cattle, as Pearson has shown, has jeopardized the forest of the future. It is suggested as a possibility that woods rodents, such as, for example, the porcupine and certain tree squirrels, and even forest game, having in places less timber to work on, and being relieved somewhat from the pressure of their natural enemies, the predatory animals, have sometimes become forest destroyers of considerable importance.

Many birds are known to play a significant part in extending the distribution of the thickets in which they dwell. Many years ago, Barrows[1] assigned birds an important rôle in forest rotation and in resurfacing with vegetation tracts swept bare by wind, water, fire or the hand of man. It is probable that Forbush[2] is correct in saying that birds alone would shortly replant all cleared lands were it not for the various tools of cultivation. Crows, jays and magpies have a special predilection for gathering and storing seeds. In this process many seeds are planted. Numerous other fruit and seed-eating species of birds and mammals incidentally plant trees and shrubs. The Douglas squirrel of the northwest caches the seed of the Douglas fir in the forest floor and is one of the factors which give the species a prominent place in the region.[3] The red squirrel assists in replanting hardwoods, *e.g.*, oak, beech and hickory.[4] McAtee has pointed out[5] that effective distribution of the seed of the best timber trees, as the pines, hickories, oaks and chestnuts, occurs through transportation by birds and rodents.

Bio-ecology of Watersheds

The forest and range problems are more serious and far-reaching than those that involve merely the production of timber and forage. The existence of agriculture and industry in the semiarid regions is dependent upon the successful maintenance of watersheds. This entails retention of an adequate cover of forest and lesser vegetation.

As Thornber has stated[6] the reclamation of desert lands is a very difficult matter. "The . . . tendency of all our arid lands is to revert to their natural desert condition. . . ." The history of mankind shows that the fight against the slow forces of nature has been a losing one, and "except in the Valley of the Nile, where irrigation has been carried on under peculiar conditions, we have yet to find a single example of a permanent irrigation agriculture." At the present time, various reservoirs supplying water for the farms on irrigation projects in the Southwest are silting up faster than they should. As a result of over-grazing in the past on the slopes from which the waters are derived, the former cover of perennial grasses is largely gone over vast areas. Every heavy rainstorm tears away some of the soil and carries it toward or into the storage reservoirs.

The silt question is important also in relation to the proposed water and power development of the Colorado River. The total amount of silt brought down every year by this stream was determined by Forbes in 1900 to be in the neighborhood of 61,000,000 tons, or enough to make 53 square miles of

1 Report for 1890, Chief, Division Ornithology and Mammalogy, U. S. Department of Agriculture, pp. 280–285, 1891.

2 Department Bulletin No. 9, Massachusetts Department Agriculture, p. 47, 1921.

3 Hofmann, *Ecology*, 1:53, 1920.

4 Cram, *Jour. Mammalogy*, 5:40–41, 1924.

5 Roosevelt Wild Life Bulletin 4:101, 1926.

6 Technical Bulletin No. 6, University of Arizona Agricultural Experiment Station, Jan. 15, 1926, foreword.

alluvial soil 1 foot deep.[7] Later and more accurate determinations indicate this estimate is probably only about one third of the actual amount.

Experiments have shown that the immediate run-off from non-forested areas after storms is as much as twenty-eight times as great as from forested tracts. In a similar manner, heavy grazing increases run-off through removal of vegetation or a change in its character. Forsling[8] has shown that on a 15 per cent. slope increasing the vegetation from .16 to .37 density decreased run-off 30 per cent. and erosion 60 per cent. The efficacy of different types of vegetation in the prevention of erosion is shown by the work of Miller[9] who found that on a 3.68 per cent. slope the removal by erosion of seven inches of soil will require twenty-nine years on uncultivated land, fifty-six years under continuous cultivation of corn, 150 years under continuous wheat, and 3,547 years under continuous bluegrass sod. Under a good rotation or under continuous grass, the nitrogen losses are greatly reduced.

The association is close between erosion and uncontrollable floods. According to Bennett, failure to build terraces on sloping fields and to plant grass and trees on the steeper lands accounts for much of the excess water that recently swept down the Mississippi. He further states that a wise combination of storage reservoirs, hillside terraces and use of grazing and timber lands for grass and trees will effect practical flood control as nothing else will.

Jones[10] called attention to the fact that while war changes forms of government, misuse of natural resources, and particularly soil and cover, destroys civilizations.

The Tigris and Euphrates Valleys, long before the Christian era, contained prosperous irrigated valleys and grass-covered, forested slopes. The timber on the higher regions was first removed, followed later by the destruction of the grasses on the adjacent slopes. The result is one of the great catastrophes of history, and the one-time grandeur of these nations is now but a memory.

Hewett recently called attention to a similar state of affairs in northern Africa. Written identifiable records, going back at least twelve hundred years, indicate a former time when forest and other vegetation clothed the Atlas Mountains. Removal of this vegetation evidently brought about destructive erosion, more widespread desiccation, and consequent depopulation. Rome tried to stem the tide of the advancing sand, but to no avail. Now modern France is at work on the task of attempted rehabilitation.

Brückner, Zon, Lowdermilk and others have adduced evidence to indicate that removal of forest does actually effect a change in the climate in the direction of aridity. Deforestation, desiccation, depopulation; so goes the sequence.

In many respects our own southwest is like Mesopotamia and Northern Africa. Throughout western Texas, New Mexico, Arizona and neighboring states, the vast herds of the stockmen of the early days have left their mark. Over-grazing has profoundly disturbed natural conditions. Range rodents (*e.g.*, rabbits, prairie dogs, kangaroo rats and ground squirrels), formerly in equilibrium with the vegetation, have assumed a new and destructive rôle. Domestic stock and these native rodents compete for the available grasses. The effects on the vegetation-cover are severe and when enhanced by drought are disastrous.

[7] Breazeale, Technical Bulletin No. 8, University of Arizona Agricultural Experiment Station, Mar. 1, 1926, p. 165.

[8] U. S. Forest Service Grazing Research Program, 1926.

[9] *Journal American Society Agronomy*, 18: 153–160, 1926, taken from *Biological Abstracts*, 1:130, 1926, original not seen.

[10] "Survey of the Erosion Problem," Southwestern District, U. S. Forest Service, Dec., 1928, p. 3.

Clements and other observers have found that the desert plains extending from Odessa, Texas, to Sentinel, Arizona, now supporting scattered zeric shrubs and ephemeral forms only, show relicts of a perennial grassland formation. A vast area, probably formerly protected by these perennial grasses, is now subject to cumulative destructive erosion and increasing desiccation.

Animals and Soil

There is considerable evidence that there exists a soil succession comparable to succession on the surface, each stage marked by the presence of a definite biotic formation. This succession is due in a large part to the action of organic life on the soil itself or on the physical factors influencing it. The importance of vegetation as a soil builder has often been demonstrated. Animals also are important. Not only the microfauna of the soil, but certain larger animals, as insects, worms, amphibians, reptiles, birds and mammals play a part in soil development. Every one is familiar with the earthworm's outstanding reputation as a soil maker. That other animals play an important rôle is doubtless not so widely appreciated. Yet Shaler[11] in his paper on "The Origin and Nature of Soils" says that ants produce a far greater effect on soils than earthworms. Shaler thinks the vertebrates exercise an influence on the soil perhaps as great as that of all their lower kindred. He assigns to mammals the most effective rôle of all in biotic soil influence. The ways in which animals affect soils include burrowing, storing, addition of excreta and deposit of their own dead bodies. The aggregate of soil working in the western United States by pocket gophers, ground squirrels, prairie dogs and kangaroo rats is enormous. Shaler suggests that if all the skeletons of vertebrates that have become a part of the soil since the close of the last glacial period had remained upon the surface they would probably cover the land with a layer of bony matter some feet in depth.

Bio-ecology as a Safeguard Against Economic Loss

This phase, which includes protection of trees from insects and rodents, livestock and wild game from predatory animals, and forage grasses and browse from range-destroying rodents, has received a great deal of attention. With insects the "protection" phase is by all odds the most important. With rodents it looms large also, though many species play mixed rôles and some are beneficial. The economic status of most mammals is not well known. Further research on this phase is greatly needed.

Insects are responsible for losses amounting to hundreds of millions of dollars annually to agriculture, forage and forest. Estimates of losses to crops in the United States from rodents total no less than $500,000,000 each year. Losses on the open range alone are estimated to aggregate more than $150,000,000 annually.[12] Some idea of the losses to individual states may be gained from the following estimates submitted by directors of agricultural extension, Montana, $15,000,000 to $20,000,000; North Dakota, $6,000,000 to $9,000,000; Kansas, $12,000,000; Colorado, $2,000,000; California, $20,000,000; Wyoming, 15 per cent. of all crops; Nevada, 10 to 15 per cent. of all crops, or $1,000,000; New Mexico, $1,200,000 loss to crops and double this amount to range.[13] Howard has pointed out that the people get only so much of the cultivated crops as the

[11] Twelfth Annual Report of Director of U. S. Geological Survey, Part I, Geology, pp. 213–345, 1892.

[12] Bell, Yearbook Separate No. 855, U. S. Department of Agriculture, 1920, pp. 421, 423, 1921.

[13] Bell, Yearbook Separate No. 724, same, 1917, p. 4, 1918.

insects leave over. Similarly on the range, livestock utilizes the forage left by rodents.

Predatory animals cause tremendous losses of domestic animals and valuable wild game, especially deer. A mountain lion in a good deer country will kill one deer or more per week. Losses to the livestock industry from predatory animals have been estimated at $20,000,000 to $30,000,000 annually.[14] On the other hand, the destruction of predatory animals may favor the increase of certain rodents. At the present time, losses from rodents are many times more serious than those from predatory animals. In rare instances, killing of predatory animals may even help to bring about an abnormal increase of big game, so that overpopulation, range and forest destruction and starvation of the game may occur.

Acquisition of further information on the complicated interrelationships involved should help determine the best policies to pursue to insure the greatest good to the greatest number.

Bio-ecological Relations of Game, Forest and Range

The game and fur-bearing species of animals, most of which, including fishes, game birds and game mammals, are to be found on the forested lands or on the open range areas, are legitimate integral parts of their forest and range habitats. Value of wild life is hard to estimate. It is certain, as Adams [15] has said, that the animal crops grown in forests may be made to produce an annual revenue of the utmost value in forestry. The same is probably true of small game, at least, on grazing ranges generally.

Associated with the persistent overgrazing in the southwest has been a steady decline and even extermination of valuable species of game birds; also, often, of fur-bearing and game mammals. The virtual or complete extinction of the masked bobwhite in southern Arizona may be cited as probably due to a combination of over-grazing and drought in its former range. Grinnell[16] asserts that not overshooting, but the removal through grazing by livestock of the cover of vegetation necessary for food and shelter is the principal cause of game scarcity on the national forests of California. The increased amount of silt in streams and their fluctuating volume, due largely to deforestation and overgrazing, have in many cases made streams unfit for fishes. The Kaibab deer and Yellowstone elk problems indicate the need for more information on the effects of big game on summer and winter grazing ranges, especially where this range is used at same season by domestic stock. With the increasing demand for more game and the need for augmented production of livestock, the pressure on the ranges tends to increase in severity.

Forest, Forage and Game as Crops

Forests, forage, wild game and water have always been considered gifts of nature. Even in scientific circles a full appreciation of man's influence on the production of these commodities does not seem to exist. Why should man not grow forage, timber and game on a crop basis? Yet, in America at least, these valuable resources have been utilized as *gifts* rather than developed as *crops*. One of the results is that while production in almost every other branch of agriculture has increased, in forest, forage and wild life it has decreased. The underlying principles governing the maximum production in both cases are largely bio-ecological and upon these

[14] Bell, Yearbook Separate No. 845, same, 1920, p. 289, 1921.

[15] Roosevelt Wild Life Bulletin 3: p. 656, October, 1926.

[16] *Journal of Forestry*, 22: 837–845, 1924.

must be based practices that will yield the best results.

Bio-Ecological Nature of the Problems Involved

The biota on an area at any given time presents the summation or integration of all the factors acting to produce it. Biotic as well as physical conditions are almost universally dynamic. The processes of to-day shape the results of to-morrow. Because of this incessant change in the living network and its physical habitat no satisfactory solution of any phase can be reached without a close correlation with other phases.

It thus appears that convincing results on an adequate scale can only be obtained through bio-ecological methods. The questions presented, almost infinite in their complexity, must be analyzed, so far as practicable, into their component parts for solution, the results obtained to be synthesized later into the required principles for the guidance of the future economic development of the region.

The bio-ecologist probably should be and doubtless will continue to be a specialist in some restricted field in which he will learn more and more about less and less. But if he is to discharge his true functions he must also cultivate a broad view. He should develop the links between the sciences, especially between botany, zoology, soil science, physiography, geology and engineering. He should know more and more about more and more.

It is unnecessary, however, for the zoologist to become a botanist, or the botanist a zoologist, to acquit himself creditably. We have tried to show the need for a comprehensive view of each problem as it arises, and an appreciation of the necessity for considering it both on the plant and animal sides. The plea for bio-ecology is simply one for more adequate workmanship. More thorough instruction in zoo-ecology, and especially bio-ecology, at forest schools and in the universities generally, is desirable. The higher vertebrates, especially birds and mammals in their various relations to environment, should receive more time and attention in the curriculum than they have in the past. So also should the vitally important interactions or coactions between plants and animals, and animals and plants.

A corollary of the bio-ecological theorem is that investigators must work together. The scientist must himself initiative and carry through effective cooperative research enterprises. In no field is this more pertinent than in the field of bio-ecology. Such enterprises, if given the generous support that the needs of the case require and justify, promise much for the future.

THE PROGRESS OF SCIENCE

JOHN HUNTER

1728–1793

WHY do scientists write and rewrite histories and biographies of their great men in spite of the fact that they have been written many times before? The populace might be of the opinion that if a history of a man or of an event is thoroughly investigated and published it ought to stand for all time. But there are two factors we must continually bear in mind in forming a comprehensive judgment of the lifework of any great man.

First, the great men are simply instruments in the course of a historic process, their life-work is never so complete that it could not receive a broader interpretation by posterity—owing to the existence of more refined methods of investigation and more penetrating historic knowledge.

Secondly, the attitude of the human mind is continually changing; being influenced mainly by environment and heredity. The mind of any special generation is not identical with the mind of any other generation as regards its conception and viewpoint of any particular scientific phase. Furthermore, different individuals hold the same event or process in their minds in different perspectives, and the net outcome of the viewpoint of later generations is the result of fusion and compromise between many different views.

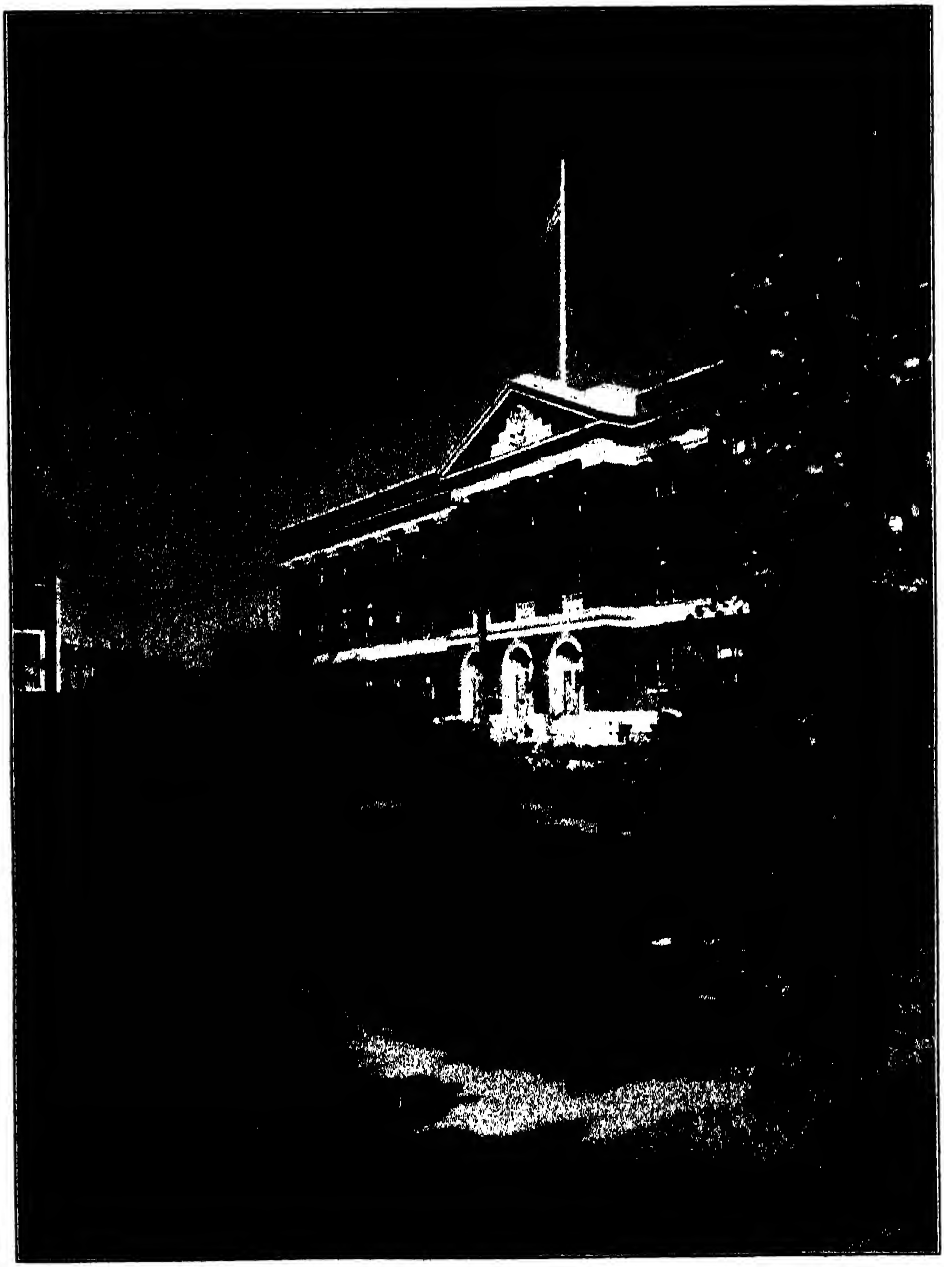
These are the obvious reasons why history and biographies will have to be written and rewritten by every new generation: their environment and necessarily their conceptions are different from ours or those of John Hunter—*Tempora mutantur et nos mutamur in illis.*

John Hunter, the illustrious English surgeon, anatomist, zoologist and physiologist, lived at a time (1728 to 1793) when a great revolution which proved disastrous for science had just passed over. The only representative of that stormy period who achieved scientific progress of enduring value was Sir Isaac Newton. In the period following this, in the eighteenth century, there was marked retrograde movement of science owing to the disorder in national and social affairs which followed the revolution. Great investigators like Hailes and Bradley are simply isolated landmarks in this historic desolation. Fifty to sixty years of complete peace, order and security brought the torch of science back to bright illumination. Toward the end of the eighteenth century and the beginning of the nineteenth century we meet with men like John Hunter, Priestley and Hutten, and at the beginning of the nineteenth century the English nation is blessed by Cavendish, Davey, Wollaston, Brewster, Herschel, Robert Brown, Dalton, Faraday, Murchison. John Hunter, the anatomist and surgeon, was born in Kilbridge, Scotland, but lived for the longest time in England itself. His parents belonged to the Protestant faith and possessed a small estate in Scotland. In the limited space permitted by the editor it is not possible to trace any effect of inheritance or enter upon a study of his personality. Those interested in these questions are referred to chapter 5, p. 121, of Hemmeter's "Master Minds in Medicine." The chapter is entitled "The Rôle and Function of Great Men in Medical History." Within the compass of this sketch the best plan to pursue is to describe in an abstracting manner his most telling contributions to medicine and science, and to leave it to the reader to form a conception of the colossal ingenuity, penetration and conservative critical judgment of this surgeon and anatomist.

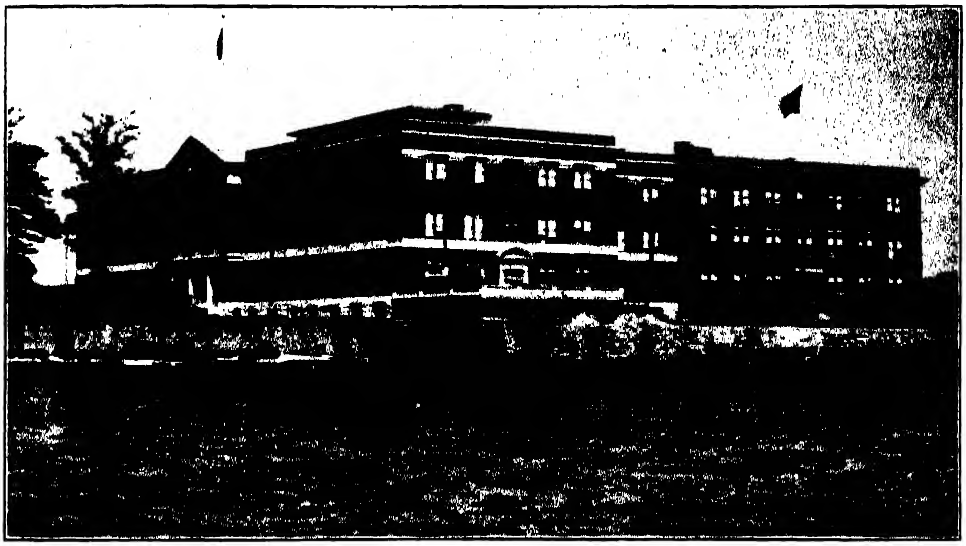
JOHN HUNTER
1728–1793

Toward the end of the eighteenth century he announced a theory of the origin of gastric ulcer and perforation, attributing them to erosions by the acid gastric juice. Although based upon the authority of Spallanzani it lost ground later on. At the present day there can be no doubt that the view of specialists concedes at least a partial correctness to the view of Hunter. In 1721 J. Hunter demonstrated that in scrotal hernia the protusion of the peritoneum preceded the descent of the gonad, and argued that the peritoneum must be pushed ahead of the intestinal loops in congenital scrotal hernia, confirming the great Haller in this view. Hunter was one of the first to state that the gastric juice had an acid reaction. Dentistry should be grateful to him because he made a condition *sine qua non* that the pulp must be completely removed if teeth are to be filled successfully. He also made experiments, and with success, to straighten and regulate teeth that were in an abnormal position. His work for dental science alone ought to attract the investigation of scientific dentists (1771). In 1773 he published an investigation concerning the electrical organ of Torpedo. In 1780 he had written several contributions to surgery which broadened the science in every direction. He had extensively practiced vivisection and experiments on animals. He ascribed the processes of inflammation to a reorganizing and reconstructive influence of the body. He was the first to describe phlebitis (inflammation of the veins). In 1785 he made one of the most epoch-making discoveries to surgery, namely, that of collateral circulation. When an artery is ligated or obstructed, the blood is forced with greater pressure and greater quantity into the side branches of the closed artery, and it eventually reaches by collateral passages the same parts which would properly have been supplied by the obstructed vessel. Upon this he founded his treatment of aneurysm by proximal ligature some distance from the aneurysm. Up to the period of antiseptic surgery this remained the prevailing and most favorite method. After that excision of the aneurysm and extirpation came into vogue. In 1786 John Hunter published his epoch-making work entitled "A Treatise on Venereal Diseases." The identity of the "*ulcus molle*" and the primary lesion were doubted by Record, but surprisingly enough the most recent investigations dependent upon the detection of spirochaetes again confirm Hunter. In 1790 he published in conjunction with the doctrine of James Moore his work entitled "On the Nature of Blood Inflammation and Gun-shot Wounds"—the scientific fundamentals for the understanding of the healing process in severed parts. In this publication he advocated the bloodless way of uniting such parts by means of bandages of strips of plaster wherever possible, and preferred this to suturing with stitches. In my work on "Master Minds in Medicine," in the chapter entitled "Leonardo da Vinci as a Scientist" I quote John Hunter's opinion of da Vinci, in order to demonstrate the astonishing erudition and breadth of knowledge in the history of medicine of this eminent English scientist. In speaking of Leonardo, Hunter expresses himself as follows: "I consider Leonardo da Vinci as the best anatomist and physiologist of his time. His teacher and he (the teacher that Hunter refers to here was Marco Antonio della Torre) were the first to know how to arouse the spirit of a study of anatomy." Hunter became a member of the Paris Academy of Sciences in 1782 at a time when only twelve other Englishmen were members of it. He possessed all the qualifications for the making of a great man that Alphonse de Candolle (1911) lists in his "History of the Sciences and Scientists since the Last Two Hundred Years."

John C. Hemmeter



THE MARINE BIOLOGICAL LABORATORY



THE MARINE BIOLOGICAL LABORATORY

THE Marine Biological Laboratory traces its origin from the establishment of the "Anderson School of Natural History" on the island of Penikese by Louis Agassiz in 1873; Agassiz died in the winter of that year, and the school was continued the following summer under the direction of his son, Alexander Agassiz, but was then abandoned. From 1880 to 1886 a seaside laboratory was maintained at Annisquam, Massachusetts, under the direction of Alpheus Hyatt, a student of Agassiz, by the Woman's Education Association of Boston in cooperation with the Boston Society of Natural History. The present organization was established and incorporated in 1888 as the result of an effort made by the group interested in the Annisquam Laboratory to secure an independent and broader foundation. A site was selected at Woods Hole and a plain wooden building, now the south wing of our large wooden laboratory, was erected here and opened for work on July 17, 1888.

The Marine Biological Laboratory was given its name and location on the seashore, because at the time of its foundation the value of the life of the ocean as material for the study of biological problems was beginning to be fully recognized after some fifteen years of fruitful activity on the part of the Naples Zoological Station. The expectations of the advantages to be derived from the study of marine material have, I venture to say, been exceeded in the results. The life of the ocean has proved our greatest asset in the contributions to the advancement of biological science made here. But this asset places no limitations on the use of the other biological materials, and in addition we draw on whatever sources of supply that inland institutions use.

The Marine Biological Laboratory is a *research* institution; all its personnel and facilities are provided to aid in the tasks of the investigators. There are officers to conduct the business of the institution, men to man the boats and nets and other apparatus with which the produce of the sea is collected; others to design and keep in order the elaborate apparatus and equipment and to assign

their use; yet others to ensure a continuous supply of sea-water to rooms and aquaria, to keep our complicated electrical system in order and attend to other mechanical needs; a department to house and feed the workers; a department to care for buildings and grounds; a library personnel and a library that we aim to make the best possible source of reference in its field. All these persons and facilities are at the service of the investigator.

Believing that it is no less our function to produce investigators than to promote the actual work of investigation, the laboratory also offers instruction to a limited group carefully selected from the best students of biology of American universities. These are the young people whose presence enlivens our proceedings for six weeks in the summer. There are also the candidates for professional status in biology, about seventy in number, graduate students beginning investigation or in early stages of a career of investigation, coming from the principal centers of biological investigation in our universities. These fortunate students receive the benefits of the standards and ideals of research of many institutions during the weeks or months of their work at Woods Hole, an advantage to be procured in no other way.

The laboratory is a *cooperative* organization. Its ownership rests in a corporation of some 350 members, the great majority of whom are professional biologists. Its affairs are administered by a board of trustees of thirty-five members elected by the corporation, composed, with but *two most valuable exceptions,* of university professors in various fields of biology of some twenty-five institutions; detailed administration is in the hands of an executive committee of five chosen by the board from its own membership. As substantially all the members of the Marine Biological Laboratory are representatives in one capacity or another of American universities, colleges and research organizations, so in practice the laboratory belongs to these institutions; here they have extra-territorial privileges and abiding place; and the contributions that they make to the support of the laboratory in return for the various uses of their biological departments constitute their recognition of this relationship. In 1924 seventy-two American institutions of learning thus contributed. This relationship is usually maintained through the university departments concerned and is continued at the pleasure of such departments; but in the case of the larger institutions it is a constant and continuing one. The smaller institutions enjoy here the same advantages as larger ones, and thus the handicaps of their necessarily less adequate provisions for research at home are to some extent equalized.

The laboratory is *national* in its scope. There is no sectionalism in its organization or in its life. It was established in New England by New Englanders and is strongly supported by the institutions of this part of the country; but it is no less strongly supported by the institutions of other eastern states; and indeed in proportion to cultural and geographical conditions by more remote states of the Union. Twenty-seven of the seventy-two cooperating institutions of 1924 lie west of the Alleghenies. Twenty-eight states of the Union were represented by the workers, and the following countries—Brazil, Canada, China, England, Holland, Hungary, Japan, Poland, Sweden. The laboratory has indeed numerous other international connections and extends its welcome to all qualified investigators of whatever nation.

The laboratory also represents all fields of biology; it is not controlled by any one biological sect, neither by Dar-

LOUIS JEAN RUDOLPHE AGASSIZ
1807–1873

NATURALIST AND FOUNDER OF THE ANDERSON SCHOOL OF NATURAL HISTORY. THE MARINE BIOLOGICAL LABORATORY IS A DIRECT DESCENDANT OF THIS PENIKESE SCHOOL.

winians or Lamarckians, by vitalists or mechanists, by zoologists or botanists, by morphologists or physiologists. It aims to provide suitable facilities for all kinds of biological work. It thus has no program of its own for the development of one or even several directions of biological investigation, save in the broadest sense. As it is catholic in its membership, so also is it catholic in its interests. This policy keeps it abreast of scientific interests; it ensures the use of means and equipment for the most promising problems of the time; it provides for a constant renewal of strength.

As part of this policy the laboratory avoids salaried appointments on its scientific staff, excepting those concerned in the courses of instruction, who receive small emoluments. The laboratory thus does not enter into competition with universities for personnel. Voluntary leadership in the various departments of biology within the institution has proved most devoted, sufficiently continuous for all matters of scientific policy and also flexible enough to avoid unprofitable specialization of the uses and of the means of the laboratory.

F. R. L.

THE HALL OF FAME

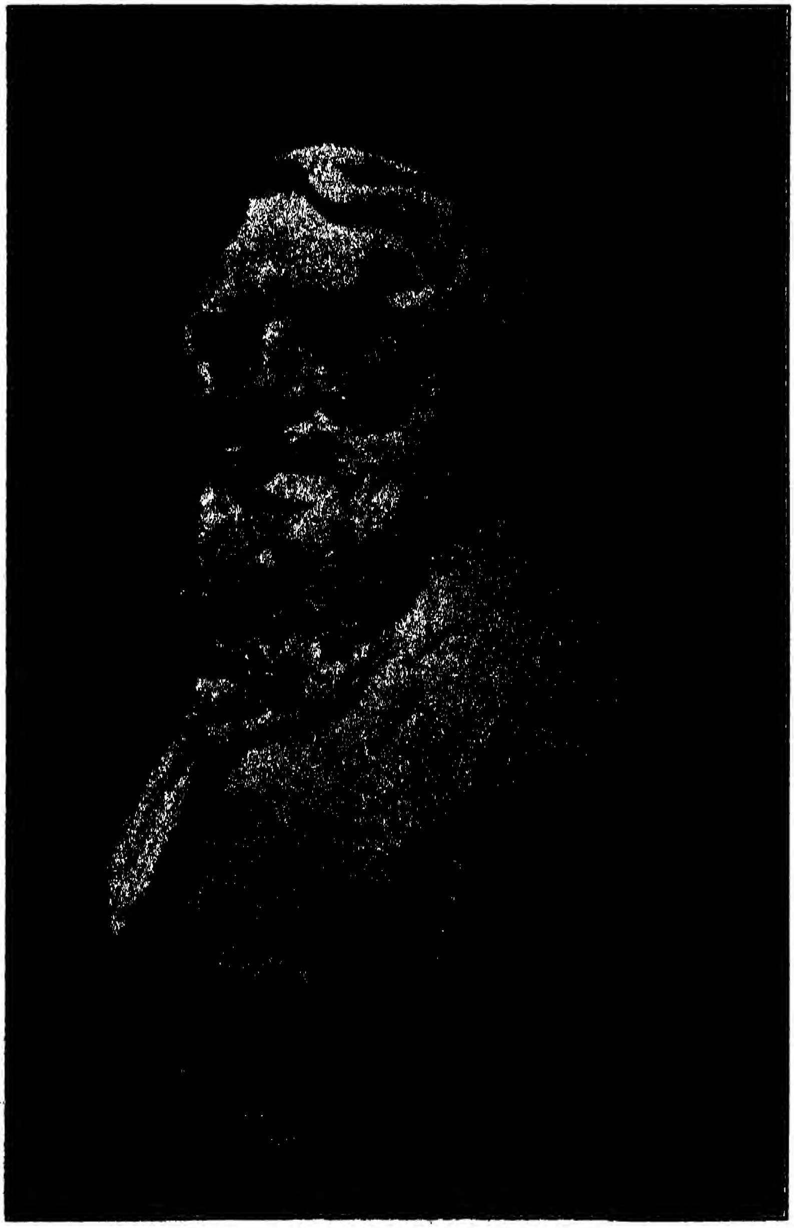
The Hall of Fame, for the immortalization of great Americans and the goal of every distinctive Yankee, is paying due homage to science. When in March, 1900, a gift of $100,000, later increased to $250,000, was made to New York University, it was established that the money should be used in building a colonnade, five hundred feet long, on University Heights, looking towards the Palisades and the Hudson and Harlem River Valleys. The substructure was to be used forever as "The Hall of Fame for Great Americans."

To this end one hundred and fifty panels were planned, to be of a size two by eight feet and to bear inscribed memorial tablets of bronze and to act as pedestals for the bronze busts. Fifty inscriptions were to be made in 1900, provided fifty names should be approved by the judges and at the close of every five years to follow another five names were to go down in bronze. The Senate of New York University, whose vote was final on whether a person should or should not be elected, were confronted with more than one thousand nominations by the hundred electors, well-known citizens throughout the country. At that time only twenty-nine received a majority of votes.

The rules were not closely followed, as can be seen in this report. In 1905 five names were added, in 1910, eight, in 1915, eight, and in 1920, six, making in all, up to 1921, a total of fifty-six names inscribed. Meanwhile seven names of women had been chosen. Had the full quota been reached in the five elections already held, seventy would have been elected, and therefore, allowing for the seven women, the quota for 1925 was twelve names. However, only two were chosen at that election. Thus the total number of tablets is now sixty-five.

Of course the Hall of Fame has a constitution, one which can be amended as readily as our national one, and it has undergone some drastic changes. Whereas, in the original Magna Charta, no foreign-born citizen was eligible to election, this unfair discrimination has been wiped out. In 1922, also, the margin of time after death at which a person becomes eligible was extended from ten to twenty-five years.

Every state in the union is represented in the electorate of the Hall of Fame to-day. The number is the same as that with which it started—one hundred persons, elected by the Senate of the university in the year preceding each quinquennial year, in fairly even numbers from various groups of citi-



SAMUEL FINLEY BREESE MORSE
1791–1872

Artist and Inventor. In 1832 Morse remarked, "if the presence of electricity can be made visible in any part of the circuit, I see no reason why intelligence may not be transmitted by electricity." In 1836 he had completed the construction of a practical electromagnetic telegraph system.

zenry, including authors, editors and artists, presidents of universities and colleges, jurists, high public officials and women of affairs. As an added precaution of fairness, no person connected with New York University is eligible as an elector.

"The public be served" might well be the motto of the institution. It is their vote which finally places the deserving ones in the position of greatest honor. Robert Underwood Johnson, director of the Hall of Fame, receives names from February 1 to March 15 of the year of quinquennial election, from all who are interested. These are in turn placed before the Senate. Before Dr. Johnson's election in 1919, Dr. Henry Mitchell McCracken, who originated the idea of the Hall of Fame, was director.

We have said that due homage is being paid to science. It is gratifying to the scientific world to know that ten scientists have been elected. The immortalized include Peter Cooper, John James Audubon, Asa Gray, Louis Agassiz, Joseph Henry, Maria Mitchell, Robert Fulton, Samuel F. B. Morse, Eli Whitney and Elias Howe.

At the most recent unveiling exercises, held on May 10, busts of the two scientists, Louis Agassiz and Samuel F. B. Morse, were dedicated. Agassiz's bust, the work of Anna Vaughn Hyatt, was the gift of the American Association for the Advancement of Science and of an admirer of the scientist. George Agassiz, a grandson of the famous man, unveiled the statue.

A granddaughter of Samuel Finley Breese Morse, Miss Leila Livingston Morse, unveiled the bust of the inventor. It was modeled by Chester Beach. Richard E. Enright, former commissioner of police of the city of New York and chairman of the Morse Hall of Fame Memorial Committee, made the presentation.

E. N.

WILLARD STRAIGHT HALL AT CORNELL UNIVERSITY

THE HEADQUARTERS OF THE FOURTH INTERNATIONAL CONGRESS OF ENTOMOLOGY WILL BE MAINTAINED IN THIS BUILDING. THE CONGRESS WILL CONVENE FROM AUGUST 12 TO 18.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1928

INSECTS: THE PEOPLE AND THE STATE

By Dr. H. T. FERNALD
AMHERST, MASS.

THROUGH all the ages two views as to the importance of insects in their relation to man have been in existence. The one may be illustrated by the statement of an old farmer who claimed that there were no insect injuries to crops when he was a boy: the other, a record of protests, in one form or another, when unusual outbreaks made destruction evident.

Probably the first view was always the result of lack of observation or apathy. It called for no action on the part of those concerned; no knowledge of what to do when treatment was needed was available; in some cases even a sort of fatalism was present, such as that expressed by the farmer who pulled out the white daisies from his fields for ten successive years and then gave up the task, stating that he believed it was foreordained that the daisies should grow on his land and that he would no longer oppose God's will.

The other view of insect importance has long been held, though often with no hope of relief. More than two thousand years ago the Mournful Prophet feelingly said: "That which the Palmerworm hath left, has the locust eaten; and that which the locust hath left, has the cankerworm eaten; and that which the cankerworm hath left, has the caterpillar eaten."

Unusual outbreaks of insects and material damage resulting have always led to the desire to do something—anything—to prevent or check the ravages of these pests, and this has manifested itself in at least two ways: the one, that of appealing for aid; the other, active, militant opposition.

The former method is well illustrated by the following clipping from a newspaper:

> July 28, 1925.—Farmers in the parish of Big Point are praying to God for the extermination of the corn borer, the destructive grub which has multiplied to an alarming extent and which threatens to totally destroy the corn crop.
>
> Sunday afternoon more than 400 people, the majority farmers and their sons, followed Rev. Father Joseph Emery around the parish. At the four corners of the parish the procession was halted while the priest offered prayers. They returned to the church where a special service of prayer was held.

Examples of the more militant way are also not unusual, though more frequent in former years. Most often the method followed was to legally cite the insects to appear before a judge in court, for trial. Here, both sides were presented by legal counsel and a verdict was given. This was "guilty" in at least nearly every case, followed by a sentence that the insects be excommunicated, and their disappearance later was considered as evidence that the sentence had been carried out.

In this country, during the early colonial and federal periods, the problem of producing a food supply sufficient to feed the people hardly existed,

but unusual losses to crops by the ravages of insects gradually turned the attention of those concerned to the situation.

The nineteenth century, however, was a period which witnessed rapid development in the United States. The colonies which had become an infant republic now became a nation. The middle west was gradually settled by emigrants from the east, and cultivation of the land increased at a wonderful pace. The introduction of the steam engine and its adaptation to ocean travel reduced the time required to cross the Atlantic from nearly a month to about twelve or fourteen days. New settlements sprang up almost over night and manufacturing began to draw its workers away from the farms, thus demanding a greater production of crops with which to feed those not occupied in raising them.

During this period, then, began the action of changes which have ever since made the subject of insect ravages of increasing importance; changes so familiar that they hardly need more than mention here.

The increasing value of food crops called for a greater acreage of them, and this meant a greater food supply for the insects attacking those crops: if an insect had ever doubted whether food sufficient for her young to reach maturity could be found, that doubt would now be dispelled for several generations at least, as she viewed the broad acres, now springing up on all sides, of the favorite food plant of her species. If European pests, hampered at home by the restraint of parasites and other enemies, had hesitated to cross the ocean for fear of death during the long voyage, the reduction of the time necessary to only two weeks would be a sufficient encouragement to attempt the crossing in the hope of obtaining escape from the fetters of their enemies in the "land of the free." After all, simply grant the possession of intelligence to insects and how similar would be the aims of both the early human and insect emigrants to this country. Favored too, at this time, by the beginning of imports of plants and other materials from Europe, there is little to wonder at if many of these brought to the United States with them insects which, escaping from their enemies in this way, could rapidly reach destructive abundance, thus adding their injuries to those of the pests native to this country.

During this period, however, the only interest shown in insects by the government appears to have been that, in connection with exploring expeditions to the unknown west, collections were made and sent to various entomologists for examination. A number of papers, valuable from the systematic standpoint, resulted, and the practice of gathering specimens in this way was continued as long as such exploring expeditions were sent out. The economic bearings of entomology, though, were not recognized. Such crop losses as occurred were either ignored or felt only locally by those most concerned. That insect pests were coming into this country was either unknown or also ignored.

Agriculture, even in its broadest phases, was practically untouched by the government and little recognition of its importance to the welfare of the nation seems to have entered the official mind, despite President Washington's ably presented arguments, until about 1839, when a small appropriation for collecting and distributing seeds, prosecuting agricultural investigations and procuring agricultural statistics was made and placed in the hands of the commissioner of patents.

Thereafter, miscellaneous articles on different phases of agriculture, and statistics on the subject, were printed in the Patent Office annual reports, the work seeming to have been organized somewhat on the basis of a division.

It seems to have been about at this

time that the idea developed that insects' injuries might, in part at least, be prevented or reduced; and by 1854 over a dozen foreign insects had reached this country, their work was beginning to be felt, and the public demand for aid on insect problems had become so strong that a "special agent, for collecting statistics and other information on seeds, fruits and insects in the United States," was commissioned June 14, 1854.

The special agent appointed was Townend Glover, born in Brazil, but of an English family, who had come to the United States in 1836 and, at the time of his appointment, was forty-one years of age. From a child he had been a lover of nature, a born collector, with strong artistic inclinations, which he developed by study in Europe, and his favorite subjects to paint were plants and animals.

In this country he settled in New York state, but was an extensive traveler, particularly in the south. Becoming interested in pomology he utilized his artist's instincts by making models of fruits and produced an extensive collection of about two thousand models.

It was these, probably, which attracted the attention of the federal authorities to Glover and led to his appointment as a "special agent," and during his first years, at least, in this position, his duties were far from being purely entomological.

One season was spent largely in Florida and resulted, among other things, in the production of the following lines:

From red-bugs and bed-bugs, from sand-flies and land-flies,
Mosquitoes, gallinippers and fleas,
From hog-ticks and dog-ticks, from hen-lice and men-lice
We pray thee, good Lord, give us ease.

The place in which Glover was obliged to work was evidently unpleasant. The entire agricultural work of the government at that time was carried on in a single basement room in the Patent Office. There Glover, his collection of models and all the material for his study sought for space in which to live, and found it not. Too cramped quarters and a satisfactory product never go together.

His official relations also, during this period, were evidently far from pleasant. Only four articles on insects by him appear in the reports from 1854 to 1858, inclusive, and early in 1859 he gave up his position, but only for more active work, teaching, writing and collecting.

During the succeeding years outside entomologists were occasionally induced to prepare articles on insects for the annual reports, but no further attempt to fill the position he left was made.

In 1862 the agricultural work was reorganized by the establishment of a department of agriculture, and the following spring Glover was appointed United States entomologist to the new department, returning to his basement room. Shortly afterward another room was found for the museum and a secretary was obtained, chiefly for clerical work.

Correspondence increased; annual reports became a burden; the museum was growing and, after a few years, an assistant—not trained in entomology, however—was employed.

In 1868, when the department moved into its new building, Glover for the first time was able to have a room in which he could keep his library and be less interrupted in his work, and here he continued until 1878, when failing health obliged him to retire.

During this period he issued seventeen reports, covering a large part of the ground of economic entomology, though doing little or nothing in the way of field observation or experiment. He apparently considered his previous travels had given him sufficient knowledge of field conditions, and experi-

mental work of any kind on insects was then unknown. Indeed, it was eight years after his appointment before the idea of combating insects by stomach poisons was developed.

Glover's work was done under conditions far from encouraging. Obliged to cover much more than entomology; with at most only one or two assistants who had no entomological training; and with his thoughts, much of the time, turned to the building up of an agricultural museum, it is not strange that his departmental work on insects is to-day of little value. His outside time was devoted to entomology, it is true, but these writings, etched on copper by hand and issued in editions of fifty copies only, were practically unobtainable. His collections? He had none. He considered the picture of an insect of much more importance than the specimen itself.

Between 1873 and 1876 much of the territory west of the Mississippi River was devastated by migrations of the Rocky Mountain locust. The complete destruction of the crops of settlers in this region and the sufferings entailed thereby created a very general feeling that steps should be taken by Congress to relieve the situation. In response, an act was passed in 1877 creating a commission to study the subject and find some method of mitigating these conditions. The government entomologist was not called upon for this purpose, but three men—Riley, then state entomologist of Missouri; Packard, well known for his studies on insects in the east, and Thomas, the state entomologist of Illinois—were selected, and the commission was at first placed under the U. S. Geological and Geographical Survey of the Territories, in the Department of the Interior, though later transferred to the Department of Agriculture. The results of this study were included in seven bulletins and five reports which, in addition to the Rocky Mountain locust, included work on cotton insects, shade-tree insects and forest insects as well. Valuable as these are, how they ever could have been published as the legitimate work of the commission is even yet not comprehended.

During Glover's later years in office, entomology began to receive more attention, and New York, Illinois and Missouri each established the position of state entomologist. It was only natural, then, that on Glover's retirement one of these should be chosen as his successor, and C. V. Riley, of Missouri, was selected.

Riley's seven Missouri reports mark the practical beginning of applied control methods. Going to Washington he brought this idea with him, and also an assistant, Theodore Pergande. In November of that year, two other assistants were added, E. A. Schwarz and L. O. Howard. Here, for the first time, we have entomologically trained assistants to work with the entomologist.

Riley had but little opportunity to develop his work, however, for in less than a year, as the result of disagreements with the commissioner, he resigned and was followed, in 1879, by Professor J. H. Comstock, of Cornell University, who, the preceding year, had been investigating cotton insects as a temporary field agent for Riley.

Comstock brought to the work the keenly analytical mind of a trained scientist. Surveying the field as it opened before him, with inquiries and pleas for aid from all parts of the country, he saw that in the scale insects there was a long list of important pests which had never been carefully studied. At first the completion of his previous investigations on cotton pests consumed his time, but during his second year he began a thoroughly scientific study of the scales and at the same time arranged that Howard, who had become his first assistant, should study thir parasites.

At this time the entomological work

was done in three rooms on the second story at the west end of the old Agricultural Building. Ascending the stairs at that end, one directly faced a door into a small room. The door was generally open, affording a fine opportunity for a study of the back of the entomologist himself bending over a microscope and often so absorbed in his work that a prolonged examination of the room and its occupant failed to produce any attention. Of the two rooms on the west end itself the first was occupied chiefly by a collection of insects which had been exhibited at the then recent Centennial Exposition at Philadelphia. In the other room the department artist, Mr. Marx, might generally be found preparing drawings of scale insects, tracing them with unerring hand on the wood blocks. Further back a young man was poring over a microscope or trying to induce some tiny scale parasite to spread its wings and legs into a position where they could be seen more clearly, by pressing or sliding the cover slip over the mount in one direction or another. At another table the wife of the entomologist was busily engaged in making drawings of insects or attending to some of the many duties of the office, while Pergande was occupied in raising insects and noting their early stages. Work, steady and hard work was the motto; as long as the light should last, at least during the short winter days of 1879—80, a winter I myself spent in Washington.

How well I remember those days. One day I saw Mr. Marx carefully drawing a tuft of pine needles with scale insects on them. Even now, after forty-seven years, I sometimes take up the report of the entomologist for 1880 and turn to Plate VI and seem to see again the artist at his work. Sometimes during the dark December afternoons the light became so poor that a little relief for the sake of tired eyes became necessary, and I remember hearing once, at such a time, the following conversation, "Mr. Marx, are you married?" "Yes." "Well, have you any family?" "Noo—but I have some shpiders," which reminds us that, though an artist by profession, he was also one of the leading arachnologists of this country.

With a change of administration, at the end of rather less than two years, Comstock retired, returning to his duties at Cornell, and Riley, in the spring of 1881, again became government entomologist, continuing in this position until June, 1894.

Upon Riley's resumption of this position his assistants became Howard, Schwarz, Pergande and B. Pickman Mann. Shortly after this time a reorganization established this branch as a division, giving it a more definite standing, which was no more than its due, as its work was now everywhere becoming appreciated. People from many parts of the country were beginning to ask for aid in the solution of their insect problems, either directly or through their congressmen, and it became both necessary and possible, with increased appropriations, to obtain more assistants. By 1888 we find, in addition to the entomologist himself, six office assistants, and eight field agents working more or less of the time, and in 1889 C. L. Marlatt joined the division. At the time of Riley's retirement a total of nine workers in the division is recorded, though the appropriations during this period rarely if ever exceeded $30,000 a year, and toward the end of each year money was frequently an almost undiscoverable article in the division, either for work or in the pockets of the members of the staff.

The most striking developments of Riley's period were: the establishment of work in bee culture and sericulture (this last discontinued later); a study of the insect food of birds, leading, after a time, to the foundation of what is now the Bureau of Biological Survey;

the discovery by Hubbard of true kerosene emulsion; the development of the cyclone or Riley nozzle, the precursor of most of our modern spray nozzles; the appointment of temporary field agents; the introduction of the vedalia into California to prey upon the fluted scale—the first attempt to utilize and increase one of nature's own control methods—and the beginning of the use of hydrocyanic acid gas as a fumigant.

Riley was a hard worker—even a hard driver—sometimes difficult to get along with; at others a delightful companion. He had a way of cutting departmental red tape which was often extremely irritating to his superior officers and which was continually getting him into trouble. Conscious of his ability, which he by no means underrated, he often seemed arrogant and impatient with others, but was always quite susceptible to flattery.

With Riley's retirement in 1894, his mantle fell upon Howard, his first assistant, who had already given fifteen years of service in the division and who now became its fourth head. During the thirty-three years which followed, he has carried on the duties of this position and laid them down only last October. But what a change has taken place during those thirty-three years! To describe the development of the work adequately during this period is wholly impossible in the time available, and only a few of its main features can be touched upon.

By the last decade of the nineteenth century this country could truly be described as wealthy. Luxuries of every kind were being brought in from all parts of the world. Rare plants, great and small, were added to those already found here, and a large importing business in these lines became established. Foreign nurseries, which were able to grow horticultural materials cheaper than we could, began shipping to the United States enormous amounts of their productions, and such material could now quickly reach this country. Little wonder was it that various insect pests from other lands could—and did—frequently appear in different parts of the United States; in fact, between 1885 and 1905 fully half a dozen insects of serious importance reached this country, some in the east, some in the south, some in the west.

Much of the work of the division of entomology during this period was, of necessity, a study of these pests, about which little or nothing was known. With the gypsy and brown-tail moths in New England, the cotton boll weevil in the south, and the San Jose scale almost everywhere, active investigation in different parts of the country became absolutely necessary, and this led to the first establishment of field stations, at points which promised the best opportunities for results, and to an increase in the number of trained workers.

The success of introducing the lady beetle enemy of the fluted scale into California—by this time repeated successfully in other countries—was most suggestive for making similar attempts with the enemies of these newly acquired residents. Accordingly, organized efforts to obtain and bring in enemies of the gypsy and brown-tail moths and of various scale insects were begun, inaugurating a new line of government work, to which the fluted scale work had been merely a preface. Cooperation with entomologists of other countries in this led to efforts to aid *them* in a similar way, resulting in the development of a large business in importing and exporting such insects as promised to be of value in the work.

Fig growing in the west had been attempted for years, but the qualities of the Smyrna fig had never been successfully obtained. One of the early problems of the division was a study of this situation, which finally led to the intro-

duction into California of the Blastophaga fig insect, which plays such an important part in caprification of the fig, and the resultant production of this fruit having a flavor equal to or even finer than the imported Smyrna figs and with a higher sugar content. Thus by the introduction and establishment of the Blastophaga, the fig trees are enabled to produce seeds, the cause of the peculiarly rich flavor of this variety of fig and permit the development of this industry in the United States.

The work of the division, under these conditions, rapidly increased. Appropriations of less than $17,000 in 1895, for actual work and with some salaries paid out of this inadequate amount, became evidently too small, and Congress, recognizing the necessity, began giving larger sums.

This growth was also marked in the other sections of the department. Agricultural demands in all lines were becoming greater, and the original building became entirely inadequate to house the activities of the department. Relief became necessary, and rented quarters were obtained in some cases, while, in part for the division of entomology, a new building was erected just southeast of the old one. This was occupied by the division in the autumn of 1895 and greatly facilitated the work.

In the early part of Dr. Howard's term there arose the problem of the insect collections which were accumulating. Housed in a crowded and nonfireproof building, the division could find neither a safe place nor room for them there. The Riley collection was already in the fireproof National Museum, where a national collection of insects would naturally be expected to be found, and in view of all these facts an arrangement was made whereby the departmental material should thereafter be concentrated in the National Museum under the supervision of Dr. Howard as honorary curator, and cared for partly by workers from the division, partly by museum workers. In this way the formation of two distinct collections, situated in different places in the same city, was avoided and the whole problem simplified. That this plan was a wise one there can be no question, and it has resulted in forming the largest collection in the United States.

This has also provided an outlet, through the publications of the museum and of the Smithsonian Institution, for the appearance of many valuable taxonomic papers which would hardly have seen the light otherwise, and left the bulletins and other publications of the division available for more economic articles, life histories, control methods and other phases of the subject.

The accomplishments just named fall far short of indicating the activities of the division between 1885 and 1910, however. Many of the older problems left from earlier days remained. Outbreaks of different insects, from time to time, required special attention; life history studies; bibliographic work, continuing that begun earlier; an increasing correspondence, and the testing of insecticides were prosecuted in addition, even more actively than before.

Just before the beginning of the present century, the relation of insects to the health of man and domestic animals also began to be realized. This was probably due, in part at least, to the work of Sir Donald Ross on mosquitoes and malaria. Here was not only a new but also an important field for entomological research, and its probable value to the people in large areas of the United States made an immediate study of the subject desirable. Beginning with studies on the life history of mosquitoes, this line of investigation has been developed more and more as the years have gone by, and other insects as possible vectors of disease have enlarged its

scope. The significance of the house fly as a vector of typhoid fever and perhaps other diseases, revealed so strikingly during the Spanish War, mosquitoes in their relations to yellow fever and many other similar insect and disease relations have now become familiar. Proof of the method of transfer of yellow fever from one person to another has become one of the most widely known instances of human self-sacrifice in the interests of science, and that this was carried out by army medical officers but shows that more than one department of the government has taken up problems in which insects are involved, for the benefit of the people.

All this time the same factors which had begun to operate nearly a century before were becoming increasingly active. More rapid transportation and the ever-growing bulk of imports from Europe, and the beginning of this now from the South and the Orient, were multiplying the opportunities for insects to reach this country, and many came. Immense tracts planted to a single crop made easy the development of various species to devastating abundance, and calls for aid in all directions became almost overwhelming. A systematized classification of the different lines undertaken, and to be undertaken, became necessary, and the division, as thus reorganized, was made a bureau on July 1, 1904. Since then a number of increases of branches or divisions have been made.

The entomologist at present is expected to be not only an entomologist but an arthropodist as well. For years pleas for aid in controlling the Texas fever tick, such a serious pest of cattle in the south, had been coming to the bureau. Taking up this subject the life of the tick was carefully studied and, in cooperation with the Bureau of Animal Industry, quarantine methods and treatments were devised for the suppression of this pest. The Bureau of Animal Industry, on taking up this regulatory work in 1906, found the tick was present in 985 counties of fifteen different states. Persistently it has moved to free one county after another until, at the present time, 760 counties and eight states have been released from quarantine. When we recall that ticks so affect the vitality of cattle, when present in abundance, as to greatly reduce the amount of milk produced and cause the cattle to become thin, weak and often die, the importance of this work to the whole south becomes evident.

Another tick, apparently not dangerous to animals but almost certainly fatal to man in some parts of the West, is the Rocky Mountain spotted fever tick. This pest too has been studied by the Bureau of Entomology and also by the U. S. Public Health Service, and a recent result has been the production of a vaccine which gives protection against the fever.

Study of insecticides on the market has shown that many were sold either with absurd claims for their effectiveness, were of no value, or were so compounded as to be dangerous to use. This led to the passage by Congress, in 1910, of the federal insecticide and fungicide act, which is to prevent the manufacture, transportation and sale of adulterated or misbranded insecticides and fungicides. To carry out this act, the Insecticide and Fungicide Board was formed, and under its supervision insecticides, fungicides and disinfectants are tested for their composition, claims made for efficiency and their action on plants. This work is done in part in the Bureau of Chemistry, where the substances are analyzed, and in part by the Bureau of Entomology at a field station where the insecticides are tested both for their effectiveness against insects and their effect on the plants involved.

In the Bureau of Chemistry this regulatory work is supplemented by research as well, both in discovering new insecticides and in finding better and less expensive ways of making the present ones. Here the recent insecticide, calcium arsenate, was largely developed, and the discovery that the insecticidal factor of pyrethrum could be extracted by the use of a mineral oil of about the distillation point of kerosene was made.

The arrival of serious pests in different parts of the country had before this time shown that entomological investigations could not always be successfully conducted at Washington but should be carried on where the insects were already present. The establishment of the field stations in Massachusetts for the study of the gypsy and brown-tail moths and in Texas for work on the boll weevil had plainly revealed their advantages. The same situation was also evident for other pests, longer in this country, which had shown variations in life or habits in different sections. The codling moth, for example, seems to lead a different life in the Hood River region of Oregon from what it does in the Ozark Mountains of Arkansas or in the hills of New England. To properly advise when and how to use control measures to the best advantage, a knowledge of local conditions is needed, and this can be obtained only by local studies. The control of the Hessian fly in Pennsylvania may be quite different from that needed in California; the bark beetles of North Carolina are not the same as those of Idaho, yet may be equally serious and need equal study.

Realization of the truth of these facts and the gratifying results obtained by the field stations first established gradually led to the formation of others, not always permanently located, but moving from time to time in accordance with any need for a change. The appearance, in 1904, of the alfalfa weevil in Utah and its spread to adjoining states has been met by local field stations for studies and control experiments. The large stock-raising districts have been areas in which to take up the insect pests of cattle, and the spread of the European corn borer has resulted in the formation of field stations in Massachusetts, New York, Ohio and Michigan.

These stations are also of use as centers from which enemies of these insects, introduced from foreign countries, can advantageously be liberated in places where their work is most likely to be an assured success, and many millions of these tiny helpers of man are thus introduced and distributed each year.

Gathering them in Europe, China, Japan, India, or wherever these enemies of our pests can best be obtained, is of itself no easy or simple problem, if any number are sent to this country. Even when once obtained there are almost innumerable difficulties in the way of getting them here in good condition, and when a shipment does thus arrive, the possibilities that some of their own enemies have come along with them can not be forgotten. Hence follows the rearing of these parasites in this country under such conditions that all their enemies, which may have accompanied them, shall be found and destroyed before they themselves are turned loose. This is work for trained experts in this line, but it is being done on a large scale and when "safety first" has finally been assured, these parasites and predators are set to work.

How great the work of importation of these foreign enemies of our present insect pests has become is not fully realized. This has been so divided among different sections of the bureau that no one seems to have thought of viewing the subject as a whole. The fullest data available, however, indicate that nearly 125 different species of parasites and predators have been successfully brought

to this country and, in many cases, hundreds of thousands of a kind liberated.

How successful they have all been in establishing themselves it is impossible to state. Over thirty are known to be actively at work destroying their old insect foods of foreign lands, here, and only time can show how many more are doing the same thing, unknown to us. Already, parasites not recovered for years after they were turned loose have at last been found hard at work, and a final verdict as to the successful establishment and efficiency of any such an insect can not safely be made for at least twenty-five years after its liberation.

Collecting the foreign enemies of our pests is most difficult without well-equipped stations at which to work and this has led, of late years, to the establishment of field stations abroad, which have already justified their existence.

As a result of the development of parasite importations and of insect studies and methods of control in the localities best adapted to such work, the number of temporary field stations has now increased to more than seventy, located in thirty-three different states, and six in other parts of the world.

Men capable of doing investigations of this kind have of course been needed, and this has led, year by year, to an increase of the staff workers and to the addition of temporary helpers during the periods when most active investigation and control experiments are being carried on. A corresponding increase in the clerical staff has also been necessary, and the roll of members of the bureau has greatly increased as new activities have been added.

But even now, more insect problems than ever before are awaiting solution. The discovery of the European corn borer in this country in 1917, first in Massachusetts, then in New York and later farther west, with its terrific menace to the welfare of our most valuable crop, has demanded that the most active and thorough measures possible be taken.

The discovery of the Japanese beetle in New Jersey in 1916 showed that another menace to our crops had reached this country, and its rapid spread and increase in abundance called for vigorous measures, not only in a study of the insect but also in quarantine work. Five stations in different places have this pest among their problems.

For this insect it has been found that though the beetle can be poisoned by lead arsenate, it is rather repelled by it, and here we have the first prominent development, at least, of the idea of using attrahents. Repellents have long been used to drive insects away, but poisoned baits appear to have been about the only place where something has been used to actually attract insects to any extent. With the Japanese beetle the idea of coating the poison with an attrahent, to induce the beetle to feed upon it, represents, in a degree, a new angle of attack upon our insect pests.

Everywhere improved control methods are also being sought, new remedies tested, and better ways in which to apply these substances. One of the latest forms of application has been that by airplane dusting, which has been tried in the forests of New England against the gypsy moth; in the central states against various insects, and in the south against cotton pests. The results of these trials have, in some cases, revealed most interesting and unsuspected facts with reference to choice of material to use, when to apply it and also the limitations of airplanes for this purpose.

As early as the year 1898 the fact that under existent conditions many foreign insects were arriving in this country on plants brought in was evident, and in his report for that year the entomologist made a plea for the pro-

tection of this country by an inspection of all materials imported which are liable to include dangerous pests. This was repeated with even greater force in the years which followed and resulted, in 1912, in the passage of an Act of Congress establishing a Federal Horticultural Board, which was given the power to establish both domestic and foreign quarantines. The former were to prevent insects prevalent in some parts of the country from passing to non-infested regions by means of shipments out of the infested districts. The foreign quarantines were for the examination of all imports into this country from abroad, which might contain pests not already here.

This established barrier lines and inspection stations with their staffs of inspectors whose duties were first, to find any pests which might be present in a shipment; and, second, to reject any shipment found infested or to so treat it as to destroy the insects. Plant diseases were also included in this work of the board.

The number of known or potential pests which have been discovered, as the result of this service, has been surprising. Menaced on the south by the fruit fly, the pink boll worm and others; on the east by the nun moth, processionary caterpillar and many other familiar European pests, and on the west by the little-known enemies of crops in the Orient, our ignorance of the insects of other countries was so evident at first that in many cases no one could say whether a particular insect found in a shipment was likely to be important if it should successfully establish itself in this country, though none of them was above suspicion in this regard.

As the result of fifteen years of work of the Federal Quarantine Board, we have to-day, protecting the borders of this country at about forty places, men inspecting imports and destroying the pests found. The states themselves are cooperating in this work and the board has this year 233 regular employees and an appropriation of over eight hundred thousand dollars. About forty of the quarantines issued are now in force, and in the case of domestic quarantines the limits of the quarantined areas are changed from time to time as the conditions with reference to the distribution of the pest change.

Though the Federal Horticultural Board is not a section of the Bureau of Entomology, the interests of the two are closely connected and, to a certain extent, interlock, while the board itself consists of members of the Bureaus of Entomology, Plant Industry and Forestry.

Such a growth as has here been sketched, in so far as the Bureau of Entomology is concerned, can perhaps be best shown by some comparisons.

When Riley retired there were nine workers in the section and a few field agents employed from time to time. On July 1, 1927, there were 530 permanent employees of the bureau, 136 in Washington and 394 in the field. Of these 530 people, 280 were carrying on professional and scientific work; eighty-seven were rated as giving subprofessional service; administrative, clerical and fiscal duties enrolled 115; twenty-four were field agents, and twenty-four more were doing janitor work of one form or another.

Drawing as close a comparison as possible between the conditions in 1894 and 1927, we find nine as compared with at least 280 scientific workers. Instead of thirty thousand dollars a year, or less, the appropriations for 1927–28 were three million, seventy-eight thousand, two hundred and sixty-five dollars, and a special appropriation for corn borer work, available during a year and a third, of ten million dollars more. By a different mode of expression, the per-

sonnel has increased since Dr. Howard became entomologist over fifty times, and the money appropriated, over one hundred times: the subjects of investigation have also multiplied, though how many times can hardly be determined.

One reason for this increase, which has not as yet been mentioned, is that modern study has shown us how little we really know of any insect. In 1896 a book on the gypsy moth was published, of which it was said that it was the most complete monograph of an insect which had ever been published. Yet, since that time, the researches of the bureau on that same insect have resulted in accumulating data to make at least two more books of the size of the first and have given much about the life of the insect which is of value as bearing on control.

New discoveries about old pests; new points in life history, habits and responses to climatic conditions: who can tell when some seemingly small discovery may not revolutionize our methods of control?

Further mention of the various lines of work which occupy the attention of the bureau would be but multiplying examples and wearying to those here to-night. Let us, rather, for a moment look at the work by the government for the people against insects as a whole.

First: Many of the very factors which have made this country a great nation have been those which would develop also a great insect population. Easy access to this country has led to an enormous immigration from abroad, both of people and of insects. Only recently have the laws against the unrestricted admission of human beings been enacted, and it is worthy of note that insect immigration was barred first. The police force—the regulatory service against foreign insects and plant diseases—was more alert than were the people, as to the nature and danger of bringing many types of foreign elements into the country. That the bars are now shut has not solved the problem: it has only narrowed it.

Second: Seventy-five years ago such a thing as economic entomology was almost unknown. We have been obliged to learn by experience what insect pests really mean to a country and then how to control them. Once begun, though, progress has been rapid.

Third: The development of entomological work by the federal government demonstrates what has just been stated. We see Glover, a good entomologist as entomologists were in those days, feeling his way along, a pioneer in a strange land, and much of the time obliged to attend to other matters. We see Comstock, the trained scientist, realizing that the true basis of successful control work must be based on a knowledge of just which insect is concerned in every case, learning to recognize them and studying their lives to discover the best places for attack. We see Riley carrying this idea still farther, seeking for new materials of warfare and new machinery to use in the war. We see the enemies' forces multiplying in numbers under our modern modes of life, and new hordes joining the enemy. And we see Howard for thirty-three years battling, at first almost alone, against the invaders and those already here; calling on all the sources of knowledge available; searching for the weak spots in the enemies' armor, and for better materials of warfare; and only recently well supported with men and money for the struggle. Attacked through our crops and with our health menaced in all parts of this broad land, the field to cover and save as much of as possible would have been too great for any one with a smaller vision, an intellect less keen and far-seeing, and a strength less great, even when the prospect of winning some particular battle

appeared to be small. There must have been some dark days, however—days when there was so much needing to be done and so little to do with. We all know these dark days, when our hopes and our plans seem destined to come to naught. Only great courage and resolution can carry one through at times.

How serious the relation between man and insects was, and is, is shown by the statement of one of the leading biologists of this country, made in the spring of 1887 to a public audience, in nearly these words:

> Man is far from being one of the most powerful of animals. The elephant, the lion, the tiger, and many others could kill him with a single blow. Yet man to-day, because of his brain power and will, dominates all creation and, so far as can now be seen, will continue to do so.
>
> The sole danger now in sight seems to be the possibility that hordes of tiny animals, themselves feeding on the plants which serve as the food of man, and with the power of increase from one to millions in a few short weeks, may so develop at some time as to destroy man by leaving him no food, though involving themselves in the same catastrophe.

With this in prospect, then—a struggle to the death—the work has developed, its many phases carefully watched and cared for, every possible source of aid utilized, and new methods of warfare developed. And now, after thirty-three years of long and most arduous service, age limitations, and these only, call for a change of leadership. It has been a truly wonderful record—those thirty-three years of service. This period has seen economic entomology grow from an infant to full man's size. And no one can deny that this growth has, to a large degree, followed from the studies carried on by the federal government in the bureau.

Those not connected with the bureau, and some of its members themselves, do not fully realize what has happened there, nor even what is now being accomplished, unless they put time and study upon its evolution since 1854. Those in the bureau hesitate to speak freely of their work. Only days of search, questioning and study of official records reveal the wealth of research, the mere outlines of which have been given here. To tell the story of seventy-five years in as many minutes is an almost impossible task, and to show that the record of growth and accomplishment has been a wonderful one is the most that can be expected within such time limits.

WHY DOES BUTTER KEEP?

By Dr. OTTO RAHN

CORNELL UNIVERSITY

SOME readers may not agree with me when I make the broad statement that butter is one of the best keeping foods known. Of course, the term good keeping is relative. Canned goods keep almost indefinitely; properly stored apples or carrots will keep a year, while meat and fish will smell badly in a couple of days, and milk will turn sour readily, if kept under ordinary household conditions. The keeping qualities of different foods are quite distinct and not comparable. Canned goods are cooked foods, sterilized by heat, enclosed in a tin which keeps all microorganisms out; and microorganisms are almost the only cause of food deterioration. Apples and carrots are living tissues and microorganisms can not exist ordinarily on the inside of healthy living tissues. The carrots are so much alive that wounds will heal over easily and growth will start at once if sufficient moisture and temperature are allowed. Apples still have a distinct respiration, but the cells of the tissues are old. Ripe apples grow no more even under the most favorable conditions (except for the seeds), and wounds do not heal; the tissue cells have lost the power of reproduction. A wound is to the apple the open door to death more frequently than to human beings. If a mold spore gets by chance into the wound, and that is very likely to happen, the apple will be rotted in a week. But as long as the waxy skin is intact, no microorganism can penetrate and spoil the apple. Fresh meat has bacteria on the outside only, derived from its surroundings, but they gradually work their way towards the inside; and in milk, bacteria are distributed evenly through the entire liquid.

Butter is neither a living tissue nor has it a natural membrane; it is not protected by a tin, and if it were, that would not help much because bacteria are distributed all through the butter as they are in milk. And yet the Dutch, Danish and German buttermakers could manufacture butter that would keep for nine months, even before Pasteur pointed out the importance of bacteria to food decompositionn, and before artificial refrigeration was known.

Not all buttermakers could make such well-keeping butter, however. It was an art, and even now when it should be a science, it is still largely an art. It should be a science because we know sufficiently well the causes of spoilage and of keeping. It is still an art because some of the knowledge is rather new, and it takes many years before the experiments of the research workers, even of the agricultural experiment stations, are generally applied.

The theories, as well as the facts, about the keeping qualities of butter have changed considerably. A century ago, in Austria and South Germany, unsalted sweet cream butter was considered the highest delicacy, but it became rancid very readily and the market demanded the better-keeping sour cream butter. Before the age of the separator, *i.e.*, before about 1880, the milk was mostly sour by the time the cream had risen; sour cream butter was the normal butter. After the separators came into more general use, sweet cream could be obtained, but it was soured by putting in some good-tasting soured milk or buttermilk, because sour cream butter as manufactured in those days kept better. Since 1890, bacteriology was introduced

into the dairy industry. The idea of souring the cream with selected pure cultures of lactic-acid-forming bacteria was tried successfully, and was later improved upon by the preceding pasteurization of the cream. In about 1900, cold storage of butter came into more general practice, and a good deal of the summer surplus of butter was kept for winter use at temperatures below the freezing point.

Pasteurization of milk or cream is supposed to kill about 99.9 per cent. of all the bacteria. Starting with a fairly old cream with 1,000,000 bacteria per cc, after pasteurization there would be only 1,000 bacteria per cc left alive. To this cream, we add 5 per cent. of a "starter," *i.e.*, a pure culture of lactic acid bacteria with an especially good flavor. The starter contains about 1,000,000,000 bacteria per cc, and 5 per cent. of it added to the pasteurized cream would give 50,000,000 cells of the desired type against 1,000 which might possibly be harmful to butter. Since the 50,000,000 lactic organisms will produce lactic acid quite readily, they should suppress any bacteria which might cause rancidity of butter, and they should also suppress any bacteria that might get into the butter during churning, salting, working and packing. We preserve many foods by acids, either by keeping them in vinegar (sweet pickles, certain meats and fish) or by letting them sour (cheese, sauerkraut, dill pickles, brine pickles). But the theory of artificial souring, simple as it is, did not prove altogether sound. One reason for this is the spoilage of butter by molds and yeasts. That rancidity is quite commonly caused not only by bacteria like *Pseudomonas fluorescens* but also by molds and especially by *Oidium lactis* and *Cladosporium butyri*, was first shown by Orla-Jensen in 1902. These molds grow better in sour milk than in fresh milk. The same holds true with the yeasts of which some species may cause rancidity. The danger from molds and yeasts is nowadays considered greater than spoilage by bacteria, and the suggestion of the Minnesota Experiment Station to judge the keeping quality of butter and the cleanliness of the butter factory by counting only yeasts and molds is gaining in application.

All the organisms spoiling butter are easily destroyed by heat, and these organisms get into the butter after the cream is pasteurized. The greatest source of contamination is the churn. Churns are made of wood. No really satisfactory substitute has yet been found. It is almost impossible to sterilize the inside of a large churn because neither steam nor strong chemicals can be applied without destructive action upon the churn. In well-conducted creameries the churn is the greatest source of infection of the cream. But molds and even yeasts might also get into the cream from the air. Bacteria live in liquids, and can not leave their medium unless this is dried and changed to dust. Molds, however, grow on the surface of liquids, and their fruiting bodies are raised above the liquid into the air. The slightest draught will carry the ripe spores of molds anywhere. *Oidium lactis* is a common inhabitant of all creameries; it grows in the buttermilk vat, on the floors and walls and ceilings of the creamery, and wherever there is moisture and the least trace of milk left on utensils, pipes, churn, etc. Glazed tiles are used in creameries not only for good appearance; the wall covering of the churning room is of considerable importance for the keeping quality of the butter.

This infection of the pasteurized cream with bacteria, yeast and molds during further treatment was found to be an essential cause of butter spoilage. But

it is not the only cause, as was shown later. The much simpler way of keeping butter at temperatures far below freezing, to prevent any microbial activities whatever, did not prove to be a complete success either. Again and again, a good deal of the butter deteriorated in cold storage, although the bacteria, yeasts and molds decreased in numbers. Evidently this was due to some chemical action, and it was especially L. A. Rogers, of the U. S. Department of Agriculture, with several associates, who attacked the problem of butter spoilage from the chemical side. The result of these long-continued investigations was the discovery that the acid of the sour cream acts upon some substance of the butter (which was later proved by H. H. Sommer to be lecithin), producing a fishy flavor. This process is greatly accelerated by the presence of metal. Traces of metal can hardly be avoided because from the time the milk is milked into a pail until the cream leaves the ripening vat and goes into the churn, it is always in contact with metal. Rogers did not succeed in obtaining, under the most carefully guarded factory conditions, a butter free from copper and iron.

Since the acidity of the cream proved to be the main factor causing spoilage, sweet cream for storage butter was tried, and the improvement in keeping quality was so conspicuous that, during the last fifteen years, almost all butter factories in the United States changed from the manufacture of sour cream butter to sweet cream butter.

This chemical deterioration of sour cream butter had not been observed before, because at temperatures above the freezing point, microbial decomposition of butter is faster than the chemical changes. It took the cold storage butter to prove that chemical deterioration takes place at all. After this had been once established, the process was also observed in butter kept above the freezing point. The dairy industry has gradually learned to manufacture a butter that contains hardly any of the microorganisms causing rancidity. Such butter shows chemical deterioration. A very striking example of this is shown in a statistical survey of recent butter contests in Germany. The majority of first and second prizes were awarded to unsalted butter, while the contrary should be expected if we consider only the preservative (anti-bacterial) influence of the salt. The reason was this, that salt also has the catalytic effect of strongly stimulating the deterioration of lecithin by acid, as H. H. Sommer has demonstrated, and the better keeping of unsalted butter, even at fairly high temperatures, is not surprising if the butter is free from fat-decomposing microorganisms.

After this discussion, the reader might doubt even more than before the initial statement that butter keeps surprisingly well. But considering the fact that the present methods of butter manufacture make it impossible to produce butter with less than 1,000 to 10,000 microorganisms per cc, that this butter is not sterilized after manufacture, and that it is not kept in airtight containers preventing contamination, but is marketed in wooden tubs and cut and weighed in the creamery or store without any aseptic precaution, its keeping qualities are most remarkable. Compare this with the much more carefully handled meat, which is free from bacteria except on the outside and which spoils so much more readily.

The reason for the comparatively good keeping qualities of butter is its structure. Butter consists of at least 80 per cent. fat, and not more than 16 per cent. moisture, the remainder being salt and curd. The moisture consists of the but-

termilk remaining in the butter from the churning and of water from the washing of the butter immediately after churning. It is distributed in the butter in small droplets, the smallest ones being smaller than the fat globules of the milk. These droplets have been recently counted and measured by Boysen, and he found that butter contained between 10,000,000,000 and 20,000,000,000 droplets per gram of butter, most of the droplets being less than 5 μ in diameter.

This distribution of the moisture in butter accounts for its good keeping. The largest number of bacteria in butter ever recorded in literature is 57,000,000 per gram. If this number is compared with the number of moisture droplets, it becomes evident that there are not nearly enough bacteria to supply every moisture droplet. Even with the most uniform distribution, only one droplet out of two hundred can contain a bacterium, and the other 199 droplets must be free from bacteria. A computation on the basis of the averages of Boysen's counts and measurements shows that of the total moisture in butter about 99.0 per cent. must be free of bacteria if the butter contains 10,000 microorganisms per gram, and that even with 10,000,000 per gram, more than half of the moisture is free from bacteria.

It is very interesting to speculate as to how this would affect spoilage. Two theories exist about the structure of butter. Fischer and Hooker, in their book on "Fatty Degeneration" (1917), mention casually that the churning process of cream might be an inversion of phases. This means that the emulsion, which we call cream, consisting of fat dispersed in skim milk, is changed in the churn to the opposite type, to an emulsion of skim milk in fat, which we call butter. This view was accepted by Gortner and Palmer, and by Hunziker; it assumes that the moisture droplets in butter are without connection, and that fat is the continuous phase. The theory of the author claims that no inversion of phases occurs in churning, but merely a tight packing of the fat globules. According to this view, the moisture droplets in butter are nothing but spaces between the fat globules, and since the fat globules of the cream have retained their membranes, these membranes of hydrated colloid form a connection between all moisture droplets so that the hydrated colloid is the continuous phase, and each fat globule is isolated from the other. The maintenance of individuality in the fat globules of butter had been claimed by B. Storch as early as 1897, and proved to a certain degree by very good darkfield micro-photographs.

A direct decision between these two viewpoints is not possible because the connecting layers between the droplets, as shown in the illustration, are less than 0.030 μ in diameter and well beyond the limit of microscopic visibility. The main point in favor of the theory of inversion of phases is the more or less spherical form of the moisture droplets in butter. They do not appear as interstices between globules would be expected to look. The main points in favor of the author's theory are the diffusion of salt into unsalted butter and the behavior of the moisture droplets toward salt. Boysen proved by micro-cinematographic photographs that the moisture of all droplets surrounding a salt crystal in butter will move toward the crystal, dissolving the salt, while the droplets disappear altogether. Since this did not occur when salt crystals were placed into a solidified emulsion of skim milk in fat, there must be some essential difference in the structure of emulsions and of butter.

The type of this structure will affect spoilage. Dr. Boysen, together with the

author, tried to get a conception of this effect by the following method. Butter was made from cream containing lactic-acid-forming bacteria. The moisture distribution was measured; the bacteria in the buttermilk were counted. From these determinations, it was found that 26.4 per cent. of the moisture of the butter contained bacteria, and the rest was free from germs. The butter and the buttermilk were placed in the 20° C incubator, and the amount of acid formed per 100 cc of moisture in the butter, and per 100 cc of buttermilk, was determined in short intervals. Since the butter was not washed, the composition of the moisture in the butter corresponded directly to that of buttermilk; both had also the same kinds and numbers of bacteria. If they did not produce the same acidity the difference could be due only to the moisture distribution in butter. This experiment and also several others, showed that in the first two days the amount of acid formed in butter did not exceed 26.4 per cent. of the acid formed in buttermilk. But after the second day, the acidity in the butter increased beyond this percentage. The increase can be explained only by diffusion, because the assumed connecting channels between the moisture droplets are far too narrow to permit the passage of bacteria from an infected droplet to one free from bacteria. Special experiments proved that no trace of lactic acid diffused through a layer of 5 mm of fat in three months, and the increasing acid formation beyond the percentage of infected moisture speaks in favor of the assumption of a continuous watery phase in butter.

The fact that there is a considerable amount of moisture free from bacteria is independent of any theory of structure and explains some facts about the keeping of butter hitherto inexplainable. The most important is probably the effect of washing. Cream is usually churned until butter granules have developed to the size of a pinhead, or, at the utmost, that of a pea. Then the buttermilk is drained off and cold water is added, and after a few turns of the churn this water is replaced by new water, the rule being that butter should be washed until the wash water remains clear. Thirty years ago this washing process was not as universally adopted as it is now, and some dairy scientists were opposed to it. But with the present standing of technique, washed butter keeps very much better than unwashed butter. If we make a chemical analysis of such butter samples, however, we find that the washing has not removed very much of those constituents which support microbial development; namely, proteins and milk sugar. Only about half of the sugar and one fourth of the protein is washed off. In a milk diluted one half with water, bacteria would grow almost as fast as in undiluted milk. Improved keeping through washing can not, therefore, be explained on the basis of dilution of food. But it can be accounted for physically.

If we assume that butter forms through a sticking together of fat globules, the small moisture droplets are the spaces between the fat globules. This assumption is supported by the fact that the number of moisture droplets is of the same order of magnitude as that of the fat globules. Many thousands of such small droplets are contained in a butter granule of the size of a pinhead. These droplets are so firmly enclosed that wash water can not penetrate them. They continue to contain pure buttermilk. Washing removes just the buttermilk from the outside of the granules. When the butter is worked, the outside moisture forms the larger moisture droplets. Thus, we have really two different sets of moisture

droplets in butter, the small ones containing buttermilk, and the larger ones containing water. In the small droplets, each bacterium has only an exceedingly small living space, and almost the entire moisture of small droplets is free from bacteria. Of the largest droplets, each one will have a few bacteria, but they have very little food. The washing has separated the bacteria from the food. This explains the great efficiency of washing, even though the amount of protein and sugar removed is very small.

The amount of infected moisture will decrease if the number of droplets is increased, or the size of the droplets is lessened. This can be done by continued working of the butter. There is a practical limit to this, as the texture of the butter suffers from overworking; the butter becomes salvy. Comparative experiments with normal working of butter, and working to the limit, showed that, in the average, bacterial decomposition could be reduced about 40 per cent. But the greatest chances for improving the keeping qualities are in the reduction of the number of bacteria in butter; for the proportions of infected moisture for average butter are:

With 100,000 bacteria per gram–12.0 per cent.
" 10,000 " " " – 1.0 per cent.
" 1,000 " " " – 0.02 per cent.

These deductions will not hold true for molds, because molds can force their way mechanically through such thin hindrances as fat globules. They have been found capable of perforating even thin tin-foil.

Looking back from our present knowledge to the earlier views on the prerequisites of good keeping butter, we can understand, if we remember conditions then prevalent, why washing was once considered dangerous to its keeping. The wash water in most of the small butter factories of thirty years ago was not good, and probably contained almost always *Pseudomonas fluorescens,* which makes butter rancid very readily. This bacterium is held in check by the acid produced in sour milk. Washing removed the lactose from the larger droplets and thus prevented acid-formation. Hence, washing did not improve the keeping qualities of butter until the wash water was made safe.

The same principle of growth-prevention by acid was thought to safeguard butter against most microbial attacks, and therefore souring of pasteurized cream was considered the best policy possible. Facts did not bear out this theory consistently, but the principle was adhered to until the stimulation of chemical deterioration was proved. Then sweet cream butter was churned, directly from the pasteurizer and cooler. Quite recently, a number of dairy scientists have been advising that a pure-culture 'starter' be added to the pasteurized cream, and bacteria allowed to develop sufficiently for the production of a good butter aroma, but not far enough to make acid.

Even our conceptions of the preservation of butter by salt are undergoing a change. Unquestionably, salt greatly retards microbial development, but it greatly increases chemical deterioration. As long as it was not possible to produce a butter with a very small bacteria content, salted butter kept better. Now, since the well-trained buttermaker can make a product which contains very few harmful microorganisms, the unsalted butter will keep better than salted butter.

Butter has an exceedingly interesting but also exceedingly complicated structure, and we are just beginning to understand its physical composition. A more complete understanding might possibly reverse again the methods for manufacturing a product which keeps well.

THE FORMATION OF THE ELITE

By Professor HENRY M. LE CHATELIER

MEMBER OF THE INSTITUTE OF FRANCE, AND PROFESSOR IN THE FACULTY OF SCIENCE, UNIVERSITY OF PARIS

(Translated by PROFESSOR RALPH E. OESPER, University of Cincinnati)

EVERY school gains renown not only through the scientific achievements of its professors, but also because of the industrial successes of its former students. Schools have been a potent factor in the development of an intellectual élite, the class responsible for the progress of civilization in any country. If Europe is superior to Africa, the sole cause lies in the possession of leaders. The blacks of savage countries may be good manual laborers, but they lack a select class to direct them, either as governing officials, as officers in warfare, as scholars, as engineers or as organizers of their industries. The formation of an intellectual superior class should be the dominant preoccupation of any country that expects to cut a figure in world affairs.

The geologist, de Lapparent, in a didactic statement declared that every terrain is, of necessity, divided into three strata: the upper, the middle and the lower. The intellectuals likewise may be placed on three levels: the men of genius, whose fame and influence extend throughout the world for many centuries; the great men, whose renown, however great at a given time, is finally eclipsed by that of their successors, and lastly, the lower élite, who temporarily exert a useful influence within rather narrow boundaries, but never attain far-reaching notability. Each of these three categories of intellectual superiors renders about the same volume of service to humanity; the men of genius are certainly the greatest benefactors, but they also occur most seldom. In algebraic terms, the product of the number in each class multiplied by each individual's usefulness gives a constant.

In a talk to the students of an American university Carnegie said, "I am speaking only to those of you who are ambitious to become millionaires; the others do not interest me." The present speaker wishes to emphasize a parallel thought: "I am speaking only to those of you who have an ambition to raise yourselves above the average, and I believe this will include all of you." It would surely be folly for any one to deliberately set out to become a genius, because this goal can only be reached through certain exceptional qualities, but we all can and should strive to be numbered among the élite, to use this term in its proper sense. With the exception of certain afflicted individuals, fortunately not numerous, all of us from birth have the requisite qualities. The rest is dependent on will power and on the method of developing and applying our natural endowments.

Let us examine together, using the experimental method, the conditions attendant upon the recruitment of the intellectual élite. For this purpose we need not distinguish the levels of attainment, for they do not differ in nature, but only in degree. We can then cite as examples great men with whose lives you are more familiar, and from these we may draw conclusions applicable to the formation of the ordinary élite. What qualities are essential and how may these be developed?

Activity

The most striking characteristic of great men is their zeal for work. None of them observed the eight-hour day, no matter what the field of their activities. We may cite as examples great statesmen, such as Napoleon or Louis XIV; great writers, such as Victor Hugo or Lamartine; great artists, such as Michelangelo or Leonardo da Vinci; great scientists, such as Lavoisier or Pasteur; great manufacturers, such as Bessemer or Siemens. In truth, they often employed the most varied ruses to protect their working periods from interruption. Napoleon assembled his ministerial council during the soirees at the Tuileries, leaving the reception of the guests to the Empress Josephine. Buffon took refuge in his country house and there peacefully wrote his natural history. Descartes secreted himself in a little Dutch village when he desired to cultivate his philosophical meditations. The labor expended by celebrated men is sometimes greatly underestimated. Powers of extemporaneous speaking far beyond reality are often ascribed to great orators. As a matter of fact, the most successful of them write out their addresses in full before delivering them. Mistaken notions as to this have originated from false claims. Emile Zola pretended that his voluminous literary output required only three hours' daily toil. Perhaps he did not actually keep the pen in his hand longer than that, but the final wording comprises only a small part of literary production.

Francisque Sarcey, while discussing the art of lecturing, very judicially analyzed the importance of preliminary work. He said:

> The title of a lecture should be chosen a month in advance of the delivery; then the subject matter should be considered for two weeks during every free moment, especially while strolling about. By degrees, new and interesting points of view will appear spontaneously, these should be classified either in the memory or jotted down systematically. During the third week, the material thus accumulated should be gone over mentally, the less important points rejected or suppressed, the others rearranged in their logical order and the connecting thoughts brought to light. At last, during the fourth week, the final wording is committed to paper and this requires no great effort.

Great men have not only labored much, but their efforts have been confined to a few specialties, thus increasing the intensity of their work. In hydrostatics a force is concentrated on a piston of small area in order to produce great pressures. Saint Claire Deville devoted half of his career to the study of dissociation. Berthelot worked fifteen years on organic synthesis, fifteen years on thermochemistry and fifteen years on agricultural chemistry. Many scientists owe their fame to studies made in a single field as instanced by Pasteur in microbiology, Fresnel with the theory of light, Ampere and the laws of electrodynamics. The same holds true in industrial applications and as examples we have Vicat and hydraulic cements or Fourneyron and the turbine.

This concentration of effort can not be recommended too highly to young investigators, for they frequently exhibit an opposite tendency and allow themselves to be enticed from one thing to another by topics which appeal to them. Only men of exceptional endowments, like Leonardo da Vinci or Lavoisier, can successfully distribute their efforts without paralyzing their creative powers. Some scholars carry this specialization of their endeavors to excess and pride themselves on the extent to which they disregard the obligations of daily life. Many stories in this vein are related of Ampere and of Henri Poincaré. The following actual

occurrence illustrates the same point. I was invited to dine with an illustrious foreigner and on arriving at the hotel I was told by my host that his wife was ill and consequently she could not dine with us. He said, "Under these conditions will you be kind enough to order the dinner, for since I have never studied this subject, I know nothing about such matters."

It is not sufficient to work hard, but it is also essential to work efficiently, *i.e.*, time must not be wasted on useless projects. A plan of attack should be formulated in advance of starting the actual work or writing, so that there need be no hesitation. Attempts to do two things at the same time are usually fruitless, and it should be a matter of principle not to stop working until something definite has been achieved. Learn to persevere and do not hesitate to adhere to a decision made after proper reflection. It is this spirit of organization, this convergence of efforts that is so highly manifested by great political leaders such as Louvois, Napoleon, Cavour, Mussolini.

Much gain may accrue by organizing the vague, spontaneous thoughts which the mind can not suppress, even though they appear to have little value. We are always thinking about something, and this involuntary thought is much less fatiguing than mental effort consciously directed toward definite production. This preparatory reflection is sometimes erroneously regarded as being quite distinct from the real work, but this opinion is quite wrong, for preliminary thought is an essential forerunner of all creative achievement. In fact, it is just as indispensable as the final effort and the latter will certainly be of little avail if the way has not been properly prepared. If the mind could be trained not to think useless thoughts, the productive capacity would be enormously enhanced. When Newton was asked how he had discovered the laws of universal attraction, he replied: "By always thinking about them." This may be the dominant reason for the superiority of great men, but we really know very little about this fugitive thinking, whose manifestations are not external. In fact, the originators of such mental processes are sometimes not conscious of their operation, or, as we say, we are here dealing with the subconscious. Henri Poincaré claimed that he thought during sleep, and on waking would find at hand the solution of problems which had baffled him the day before. However, this is not a commendable practice, for it is opposed to the rest which each night's sleep should bring.

How may a zeal for work be developed? Is it a natural gift or is it a result of education? The greatest stimulant of activity is habit, which proverbially becomes second nature. After leading an active life, it is not possible to stop work without suffering. Idleness due to retirement rapidly kills many men who previously had enjoyed excellent health. After the habit of working is once formed, a man will work for the mere joy of working just as we walk for the pleasure of the exercise. It has become a necessity.

However, this habit is not easily acquired. Temperament plays some part. Certain children, from birth on, exhibit more will power, have more acute faculties of attention, are more persevering, all of which are essential to the accomplishment of a protracted task. Yet these predispositions are, in general, developed only to a slight degree and play only a minor part in the differentiation of individuals. Other factors seem to be of greater importance.

The example of the home and of companions exercises a preponderant influence. A child who all his life has seen an industrious father will merely through imitation be led to accept the law of the obligation to work. Pascal, Lavoisier, Pasteur were raised in families in which honor was paid to industry. Whether the latter is intellectual or manual matters little. Very few, or perhaps no great men, have come from the families of the idle rich.

A second very potent factor is ambition, that is the desire to acquire riches or honors. Men not favored by the fortunes of birth sometimes struggle with extreme energy to make a place for themselves. A striking instance of the power of ambition is found in the career of Senator Leopold Goirand, who died recently. He published some essays on education which reveal curious points in his psychological makeup. At the age of fifteen, he conceived the dual ambition to become very rich and to attain a powerful political position. He succeeded in both endeavors. For twenty years he forced himself to be content with six hours of sleep each night in order to lengthen his working day. Each morning on arising he spent two hours acquiring general culture, the rest of the day was devoted to his business, and finally the evenings were passed in attendance on social affairs, for the latter are extremely useful in the prosecution of a career. Not until his physician warned him that he was no longer fit to continue this program did he consent to sleep eight hours nightly. Many similar examples may be cited.

In Bessemer's autobiography, which is a veritable romance, he tells of his superhuman efforts, as a young man, to earn enough money to marry. While Cavour was striving to create the Italian kingdom, he allowed himself only five hours' sleep each night so that he might have time for the stupendous task whose realization had been the dream of his whole life. He took over the direction of four ministries at one time.

A third stimulus, more noble than those already discussed, is the attraction inherent in the fruits of labor, *i.e.*, the joy of knowledge and the pleasure of performance. The passion for knowledge or for success in a chosen field often arouses men who by temperament or habit might have been inclined to loaf. A pertinent example is Mallard, one of the scientific glories of France. Like many others who graduated from the Ecole Polytechnique at the top of the class he seemed to be destined for a standardized, peaceful career in the governmental service. As engineer at Gueret and then as professor at Saint Etienne he divided his activity between long journeys and everyday affairs, attending to his administrative duties and his teaching. At the age of forty he was appointed professor of mineralogy in the School of Mines in Paris, and consequently because of his teaching duties he found himself obliged to study this science. He became deeply interested in one of its branches, crystallography, and for twenty years, until his death, all his efforts were concentrated in this field. He succeeded in working out original demonstrations of the laws of crystallography and he created a new chapter in this field, the theory of crystalline groupings.

Many similar cases are found among scholars, for many of them are motivated chiefly by the joy of knowledge. On the other hand, examples of this disinterested activity are less frequent among industrialists. However, the pleasure of achievement rather than the mere love of gain has actuated the

greatest of these. The optician Zeiss worked for the glory of his country, Germany, and his native city, Jena. The Danish brewer Jacobsen engaged in business only to gain the means of endowing the museums and laboratories of Copenhagen, which have become world famous. The American millionaire Carnegie while a young man spent his free time in libraries solely because of his desire to learn. He later devoted the major portion of his immense wealth to the development of public libraries and to the founding of an institute of scientific research. Henry Ford left the farm and worked in a locksmith's establishment because of a desire to learn the use of tools, and even now he continues in business because he derives great pleasure from heading a well-organized industry. I knew two contractors who had taken part in the construction of the Suez Canal. They retired from business and took up agriculture. One engaged in stock-raising, the other developed a model farm. They devoted all their energies to the enterprises and ran them so that the receipts and expenses balanced, neither profit nor loss resulting. Their sole ambition was to do a good piece of work and to turn out products of superior quality.

This joy in work may be developed by education and without difficulty. Success is assured if less attention is given to preparing for examinations and more stress laid on the intellectual molding of the children. From their earliest years they have a wide-awake curiosity, they continually ask why and how. Instead of eradicating this disposition, it should be cultivated. Science courses lend themselves wonderfully to this end. Emphasis should be placed on the linking together of facts, which is the essence of the scientific method, discarding the fastidious enumeration of isolated facts which so overburden the memories of pupils to-day. Any child can be interested in the consequences of Pascal's laws of hydrostatics and made anxious to work diligently to understand them. A study of Archimedes' principle, applied to floating bodies, of hydrometers, of water levels in connecting vessels, of atmospheric pressure—all these may be grouped around Pascal's laws and thus made into an attractive ensemble. It is wrong to treat each of these topics as a separate chapter as many physics texts do, for then the intimate relationships disappear from view and likewise all attractiveness is lost.

Manual exercises should be included in the secondary curriculum because the formation of ideas in young people is rendered more easy and pleasant by combining sight and touch. They love motion. For instance, when teaching hydrostatics, the pupils may be directed to cut cubes from various kinds of wood, to measure them, to weigh them and finally to determine the loss in weight when the cubes are immersed in water. An exercise of this kind makes the appreciation of Archimedes' principle pleasurable. In the same way, preliminary exercises in graphic plan-making lead to a much easier understanding of geometrical reasoning. Much less intellectual effort is required to comprehend the demonstration of a truth if actual experimentation has previously made the reality familiar.

A final incentive to the ardor for work is good health. The thought of working or still more of getting to work, *i.e.*, the wish to do something, involves, if not a true fatigue, at least a feeling of fatigue which leads many to shrink back. A good digestion and restful sleep make the thought of work much more agreeable. This does not

imply that a strong will can not overcome the weakness arising from poor health, for there are remarkable instances of such victories, but they are rather exceptional. Pascal subdued his infirmities, but the strain finally killed him. Health always is a great driving power, and the truth of the axiom, "*mens sana in corpore sano,*" can not be debated. Physical culture should occupy an important place in the education of the young; it is indispensable in the formation of the intellectual élite of a nation. However, it must not be forgotten that muscular fatigue renders all mental labor impossible for the time being. The physical exercise should follow intellectual exertion, but should never precede. While in Holland, Descartes devoted his mornings to philosophy and cultivated his garden in the afternoons.

Imagination

A useful member of society does not merely work hard and produce much for his own benefit; he should add to the common fund of knowledge. In other words, he must produce new ideas, discover scientific laws, devise new literary or artistic presentations, perfect methods of government; in short, he must play a creative rôle.

What is the mechanism by which this progress is realized? Contrary to popular belief, our knowledge does not increase by leaps and bounds, but the development is regular and very slow. Each step forward, in the majority of cases, comes from the simple combination of facts previously known. It is only necessary to delve in the storehouse of knowledge and to bring new relations to light. This correlation is a fruit of the mental faculty, imagination, whose functioning is rather capricious. The solution of a problem may be sought unsuccessfully for a long time, and then suddenly it may flash into the mind at a time when the problem is no longer being consciously considered.

The work of all great men shows the employment of imagination; it constitutes the beginning of all great discoveries. Pascal created hydrostatics by connecting the limitation of the height of a barometric column with the weight of the atmosphere; Newton discovered universal gravitation by comparing the movement of the planets with the fall of an apple; Pasteur founded microbiology by connecting the spread of disease with the life processes of microscopic organisms. Likewise, in the field of letters, we find writers dealing with ideas common to all humanity and sending them forth in new attire. La Fontaine gave life to Aesop's fables by endowing the animals with speech; Corneille introduced a sense of duty magnified almost to heroism into the Spanish dramas. Artists sometimes slightly exaggerate certain features of their models to produce a more striking representation. Michelangelo accentuated the muscular development of heroic figures and Raphael the grace of women.

The same is true in industry. Sir William Siemens applied the theoretical reasoning of Sadi-Carnot to the heating of hearths, and the regenerative furnace resulted. He invented neither thermodynamics nor industrial heating, but by uniting these two sets of facts, he brought about a great advance, which made possible the modern processes of making steel in open hearths and of glass in tank furnaces. All inventors possess this mental activity, sometimes to excess. It is interesting to read Bessemer's autobiography from this point of view. We see his mind always in feverish agitation, trying each day to produce something new, usually without success.

This first type of imagination is meditative. It acts slowly, and to a certain degree may be governed by the will. There is a second type, rather more delicate in nature, whose action is sudden and not preceded by reflection. It is this type which enables us to see at a glance all the correlations and distant consequences of a chance observation. The predisposing factors are impressionability and nervous sensibility. This quality varies greatly from individual to individual, certain minds respond to the slightest external suggestion, while others feel nothing, see nothing. In general, great scholars are characterized by a highly developed aptitude for sensing and using facts presented to them. The accidental observation that his determinations of the density of nitrogen were discordant led Lord Rayleigh to the discovery of argon. Other investigators had been faced with the same phenomenon, but were not markedly impressed. While attempting to fuse platinum, Saint Claire Deville was struck by the difference between the calculated temperature of the oxy-hydrogen flame and the observed melting point of platinum. This led him to suspect the dissociation of water vapor, while his collaborators, possessed of the same facts, thought nothing of them. Similarly, Bessemer was led to his process of producing steel in a converter by the fortuitous observation of the formation of malleable steel during an attempt to harden cast iron. Or better still, Auer von Welsbach discovered the incandescent mantle through a chance observation of the light emitted on calcination of precipitated thoria. Numerous analytical chemists had doubtless seen the same thing, but their attention was not arrested.

Great artists viewing nature, great generals before a battle, great lawyers before a trial are sensible to instantaneous impressions which escape the notice of ordinary men. The two types of intellectual activity seem to be predominantly natural endowments. Some children have wide-awake minds, others are more dull and remain thus throughout life.

This quality may, however, be developed by education, and more attention should be paid to this phase of education than is usually the case. Exercises in written composition, problems in geometry, afford excellent material from which to build up mental habits of using accumulated knowledge or of seeking new correlations of known facts. This type of training is doubtless the most useful function of secondary education. On the other hand, education can not develop the second type of mental activity which is not dependent on reflection, but which functions instantly in some way not known to us. Nevertheless, there seems to be some possibility of perfecting this natural endowment by suitable laboratory exercises.

Judgment

The combining of imagination and work, *i.e.*, intellectual activity joined to bodily activity, does not entirely suffice for the making of a great man. Excellent examples are inventors, who almost without exception are possessed of active minds and an equal ardor for work, and yet few of them become great. In fact, many of them have difficulty in making both ends meet and remain mediocrities. The two qualities can only be used efficiently if joined with a third, namely, common sense. This latter, if developed to its highest degree, becomes what Pascal has called the sense of finesse. Bodily and mental activity are certainly powerful instruments, but like all aids they must be

used judiciously. Common sense should guide the choice of problems to be studied.

One of the most potent reasons for the success of great men is that they were wise enough to apply their efforts to worth-while problems. Why will the names of Lavoisier, Sadi-Carnot, Ampere, Fresnel, Saint Claire Deville, Berthelot always be famous? It is because of the greatness of the topics they studied. The results of their discoveries in chemistry, thermodynamics, electrodynamics, physical optics, chemical mechanics, organic synthesis have echoed again and again, and the reverberations are daily multiplied.

Many years ago Taine said that the systematic study of the dominant features of his subject was the essential characteristic of the work of a true artist. The same holds true in all realms of human activity. There are dominant phenomena whose influence is felt under most manifold circumstances. A knowledge of these favoring factors is of inestimable value to the human race, and their discoverers merit suitable recognition on the part of their fellowmen.

A second form of judgment is "critical sense," indispensable to both scholar and to those directing industries. This gift makes possible the detection of errors in measurements or leads to a premonition against erroneous interpretations of observations. It is often lacking in inventors, who are prone to persist in their notions despite self-evident failures. Lesser intellectual lights also can not bring themselves to abandon favorite hypotheses which are not in agreement with the facts; they seek refuge in new additional hypotheses and cling fast to the original notion. Ditte, a pupil of Saint Claire Deville, furnished a striking example of this type of mental gymnastics. While trying to extend the law of fixed dissociation tensions to the decomposition of solutions of mercuric sulfate he found that the concentration of the liquid with respect to sulfuric acid increased with increasing concentration of mercuric sulfate. Instead of abandoning his hypothesis, which was obviously inaccurate, he introduced a second, which to-day appears absurd, but for a time it enjoyed a certain credence among chemists. He postulated that the dissolved mercuric sulfate was present in two forms, part as neutral salt and part as basic salt, dissolved in, but not combined with, sulfuric acid. He calculated the proportion of the basic salt supposedly thus dissolved which would leave a constant concentration of sulfuric acid in solution, and he viewed the results of this arbitrary calculation as experimental verification of his hypothesis. This species of error is constantly perpetrated nowadays by those who speculate as to the constitution of matter. Savants who, like Lavoisier, Claude Bernard, Pasteur, combine an ever-watchful imagination with a critical sense severe enough to lead them to discard hypotheses found contrary to fact are extremely rare.

Finally, there is a still more refined form of common sense, namely, the sense of subtle discrimination which enables us to guide our minds directly into domains of thought which are not perfectly obvious. It is often asserted that hypotheses are free to all, an investigator may postulate what he pleases, provided he finally subjects his notions to precise, experimental test. However, it is distinctly worth while not to set up too many inexact hypotheses, for time should be economized to the end that production may be increased. A certain instinctive discernment is necessary to set one rapidly on the best line of procedure. Rules for

this can not be laid down; it is a matter of feeling and not of reason. The remarkable productivity of Pasteur was doubtless due to his ability, from the very first, to thoroughly organize his researches. Sometimes this ability is ascribed to chance, but this is not correct, for we see here the fruit of a very shrewd form of common sense. Saint Claire Deville's thought that there might be a possible analogy between the phenomena of decomposition and those of vaporization was an intuition of genius; it led him to the discovery of chemical equilibrium, which he termed dissociation, and a new science, chemical mechanics, has been erected on this idea.

Good common sense is often a gift of nature, but the more delicate sense of subtle discrimination is principally a result of education. It is very rarely observed among the children of the lower grades; it is a product of classical education, and, above all, it springs from that which is taught in the home. The English declare that thirty-six years of education are necessary to make a gentleman, twelve for the grandfather, twelve for the father and twelve for the son. The same holds true for this sense of finesse. Pascal, Lavoisier, scholars of the first rank, came from families of long-standing culture, and their successes were due in large measure to the prolonged efforts of their ancestors.

The study of classics and humanities aids in developing this trait. Literary or historical criticism requires a constant evaluation of opposing points of view to determine the part played by each in domains not amenable to exact measurement. On the other hand, the study of science develops the geometrical viewpoint, *i.e.*, the use of syllogism, which is utterly useless when comparing phenomena possessing no common measure or such as are based on mere probabilities. The exclusive use of rigorous reasoning and an absolute faith in his conclusions are sometimes very dangerous to a savant. They hinder him from taking account of the real value of the hypotheses which he has made and from recognizing the possible errors in his experiments. These modes of thought are not less hazardous to the industrialist to whom they may impart an unwarranted confidence in the predictions as to the advantages of a new business venture or of a new method of manufacture.

Documentation

Many of the essentials for laying claim to a right to be numbered among the intellectual élite have been discussed above, but not all. Suppose that a savage has had from birth all the qualities which we have just reviewed, but that he is entirely ignorant of the progress of the science and industry of the civilized world. It would be extremely difficult for him to advance our knowledge, for he knows nothing about such matters. He can accomplish feats which to him seem extraordinarily difficult, such as cutting flint or extracting iron from ores, just as his ancestors did. To us, however, he would seem ignorant and no one would dream of classing him as a great man.

No one can make innovations or improve our knowledge unless he is cognizant of actual conditions. There are several reasons why this is so. In the first place, one can obviously improve only those things which he really knows. A frequent cause of the failure of inventors is that they knowingly venture into unfamiliar fields. Bessemer, the son of a metallurgist, advanced the science of metallurgy, but made a miserable failure when he attempted to build a large telescope and also when he tried to construct a boat designed to prevent

seasickness, because he knew little or nothing about the theory of optical instruments or of mechanical principles.

While serving on a commission appointed to investigate fire damp, I met a physician, intelligent, possessed of a good practice, but obsessed by the demon of invention. Much affected by an explosion in which several hundred miners had been killed, he thought it would be a good thing to send a current of air through the mine to sweep out the explosive gases and thus obviate such disasters. He disclosed his plan to an official in the Department of Public Works, and the latter warmly congratulated him on his initiative. This unfortunate encouragement led him to abandon his practice for a year and he devoted himself to the construction of a ventilating system. We were obliged to inform him that every coal mine in the world is ventilated. Furthermore, twenty kilometers from his home he could have seen in action immense installations which closely resembled the blowing apparatus which he had worked out, and this device differed but slightly from the bellows used for several thousands of years by savages for melting metals.

A second reason for being well acquainted with the field arises from the fact that all creative advances, all discoveries are, for the most part, the result of combining facts already known. The progress achieved by a single individual is, in general, extremely little, but among these short steps forward, one perhaps, like the last drop which causes the vessel to overflow, may make an invention realizable or it may alter the orientation of our scientific ideas.

Pasteur did not invent the communication of diseases, for this was known to all physicians, nor did he discover the existence of living microscopic organisms, which had been studied from the time of Spallanzani. He merely compared these two sets of phenomena and recognized their relations one to the other. Had he not known the facts, he could not have made the discovery. Likewise, Lavoisier did not invent the balance; it had often been used before. Every alchemist who extracted metals from ores had checked the efficiency of his procedures by weighing. On the other hand, all physicists knew that gases had weight. Lavoisier simply had to combine these facts to recognize that the increase in weight of metals when calcined in the air was due to the absorption of a gas, oxygen. The time was ripe for this discovery, and Lavoisier had only to pluck the ripened fruit.

The same holds true in industry. The open hearth process of making steel resulted from a combination of Réaumur's century-old work on the refining of cast iron and Siemen's new method of heating. In his invention of the incandescent gas mantle, von Welsbach started with Clamond's magnesia "basket" and perfected this device by substituting thoria for the magnesia. This linkage of known facts is so common that no industrial invention is so novel that the lawers can not find authorities for prior claims. For the same reason, the defamers of great scholars, great writers and great painters find great pleasure in accusing them of plagiarism. Fontaine has been reproached with having copied from Aesop, and Corneille is accused of servile imitation of Guillen de Castro.

If the popular saying, "There is nothing new under the sun," is surely not strictly true, nevertheless it is quite accurate to state that progress due to any one man is comparatively small. Humanity moves forward at a slow pace, but the thousand-fold accumula-

tion of short steps forward has altered the face of the world. This progressive revolution has only been possible because men have had a thorough knowledge of the accomplishments of their predecessors.

A third reason for being well versed is that accomplishment of anything new demands a knowledge of the technique of the field, and this has to be learned. If Bessemer had not been a founder in his youth he would never have invented his process of making steel. A thorough knowledge of analytical chemistry is essential to the making of chemical discoveries; success in literature is only possible to one who really knows his own language; a painter must know how to draw. This assertion may appear to be a step backward. Too many artists try to paint, knowing neither drawing nor manipulation of colors; too many scientists have no interest in methods involving actual measurements, they are content to construct their science with pencil and paper only. These varieties of modern painting and science are very fruitful for their devotees. However, who dares to assert that the cubists and similar faddists will some day be classed as great painters or that much of our present-day theories of the constitution of matter will be highly regarded fifty years from now. In comparison, the men who discovered new laws in chemistry, electricity, optics, etc., will be just as honored thousands of years hence, as Pythagoras, Ptolemy and Archimedes now are.

This knowledge of the field, essential to any worker who hopes to advance human welfare, may be acquired through instruction furnished by schools of all grades, from the highest to the lowest, or it may be a result of observation of the facts, *i.e.*, a fruit of the direct study of the surroundings in which we live.

No one is born with a knowledge of the outer world; this must be acquired solely from experience and toil. Certain natural endowments, memory in particular, favor the acquisition of this necessary knowledge. Many great men have had remarkable memories; Berthelot and President Poincaré are outstanding instances. The former knew the title of more than a thousand of his papers and the volume numbers of the Annales de Chimie in which they were published. It is said that Poincaré needed only to write a speech once to know it by heart. He amazed his audience at the Sorbonne by his delivery of a eulogy of the scientific achievements of Berthelot. He spoke more than an hour and a quarter, using no notes or memoranda, and yet with such precision that any one might have thought him an exceptionally well-informed chemist.

The sense of observation is no less valuable; it is essential to the completion of the fragmentary knowledge acquired by the memory during the years of schooling. As we go through life, we are confronted by a multiplicity of facts which demand our attention and efforts. They are so numerous that we can not expect to learn them from books, and, furthermore, many of them are not common knowledge and consequently can not be found in courses of instruction. Our knowledge of the world is constantly augmented by the labor of every one of us, but the contributions are extremely unequal, varying with aptitude and training. In military instruction, observation is taught by assignments in scouting. The pupil is sent to a given point and on his return he is questioned as to what he saw. Usually, he has seen nothing. He is sent back and told what to look for: the undulations of the ground, the kind of vegetation, isolated trees, hedgerows, roads, houses, the con-

tour of the horizon, and little by little the pupil improves.

High-school exercises in science should be largely planned to develop observational powers. Actual handling of apparatus and materials lends itself excellently to this end. A student is told to heat a material, say iodine, in a test tube, or to dissolve a substance, mercuric sulfate, for instance, in water, and then asked to describe all that he has seen. After he has completed his report, the instructor should point out all that actually can be observed in the experiment.

Conclusion

To sum up, we find that the formation of an intellectual élite entails the union of four qualities—industry, imagination, judgment, training. Unfortunately, these qualities are, in a certain degree, contradictory among themselves. The toiler, bound to his task like an ox to a cart, often forgets to pause and meditate; his intellectual activity slows down. The dreamer, the inventor lets himself be guided by his fancies and often lacks common sense. Finally, the abuse of book learning and memory tends to paralyze all the intellectual faculties.

It is extremely difficult to produce a perfect balancing of these diverse faculties. This fact alone is sufficient to explain the infrequency of great men and, *a fortiori,* of men of genius. It is useless to suppose, as many do, that men of genius owe their accomplishments solely to exceptional natural endowments which raise them above the common level. They have qualities which taken singly are not extraordinary, but it is the occurrence of all these qualities in a single mind that is rare.

Most men do not like to work. The suburbs of Paris are filled with small houses inhabited by rentiers, who perhaps in the beginning worked hard but only in the hope of soon being able to stop working. Unfortunately, this feeling is all too general in the Latin countries. In 1918, during the Armistice, a party of American engineers who had served as officers were taken for a boat ride down the Seine from Paris to Rouen to see the bridges, locks, etc. To them, the most striking sight was the number of fishermen lining the banks of the river. They could not believe that there were so many Frenchmen content to spend their days watching a cork float on the water, thinking nothing, doing nothing.

Intellectual industry is not much more common than bodily industry. One needs only to scan the interminable lists of candidates for petty government positions which require little, if any, mental exertion. The holders of such offices are content to repeat each day exactly what was done the day before. This apathy is apparent from childhood on. How many college students have a horror of real effort? They are satisfied to learn assigned lessons by rote, and never do more than the required amount. Indeed, they often do not try to understand what they learn.

Common sense is perhaps rarer still. In proof of this, consider the results of popular elections. The voters work painfully to make their livings and then cast their ballots for the worst wasters of the public wealth. Industrial conflicts lead to mutual ruination; efforts to squeeze the consumer, who is the goose that produces the golden eggs, bear witness to this same stupidity. Each side devotes itself to efforts to bring about a redistribution of wealth, each hoping to get the bigger share. Neither party comprehends the real problem, which should be its sole interest, *i.e.,* they should both strive for in-

creased production, which would benefit the world at large.

Finally, the question of learning what has been done and the matter of instruction and training is still in a precarious condition. The number of illiterates is still very large. Schools are often more concerned with politics and large enrollments than with the pupils. Unfortunately, this is one of the habitual wastes of democracies. In the higher schools, students obtain cheapened degrees, and higher culture is regarded with more and more contempt. The fetish of equality means a levelling on a lower plane.

Admitting what has been said, let us make a calculation. Suppose one man in ten has a love of industry; one in ten a certain intellectual activity; one in ten common sense; one in ten has been well taught. The probability that these four qualities will be found in one individual will be $(\frac{1}{10})^4$ or $\frac{1}{10,000}$, *i.e.*, one in ten thousand may be expected to belong to the intellectual élite. This is not many. The production of a great man requires the union of these same qualities, but each in full bloom. If each quality, developed to this high degree, occurs in one man in a hundred, the probability of their being thus present in a single individual is $(\frac{1}{100})^4$ or one in a hundred million. Consequently, we can explain why men of genius are so rare, without seeking the reason in the realms of wonder.

It is a very noble task to aid in the creation of an intellectual aristocracy. The prosperity and lasting glory of any country, all its future welfare, depend on the success of these efforts. Above all, this is a work of education, and no effort should be spared to realize this common good. The family should set a good example to the younger children and inculcate a taste for toil; the secondary school must develop imagination and common sense; and finally the colleges and universities must impart training.

However, an intellectual élite is not the only thing required to make a great nation. There must also be a moral élite, a great class which knows respect for the rights of others, a class to whom the Golden Rule is law, and last but not least, this class also respects and demands respect for real liberty. I do not wish to discuss this last point in detail, for it lies outside my province, and especially because we have a right to expect that the educated classes will have both a highly developed sense of duty and a profound appreciation of independence. It is their duty and privilege to set a noble example to others.

RACE CROSSING IN JAMAICA[1]

By Dr. C. B. DAVENPORT

DIRECTOR, DEPARTMENT OF GENETICS, CARNEGIE INSTITUTION OF WASHINGTON

As one travels over the world one sees that the people who inhabit its different parts differ. Thus one gets the notion that the world is inhabited by different races.

An attempt to define "race," however, is fraught with many difficulties. The difficulties are diminished by accepting the definition of students of genetics, which is as follows: A race is a group of individuals constituting a subdivision of the species characterized by the possession of some one distinctive hereditary trait. Thus, from this point of view, a blue-eyed Swede belongs to a different race from a dark-eyed Italian or even from a dark-eyed though blond-haired Swede, since eye color is an inherited trait.

Race connotes, however, a *group* of individuals having at least one and the same differential, hereditary trait. A century or two ago such human groups were found in different parts of the world fairly sharply marked off from each other. The Congo region was characterized by a group of persons with black skin, broad nose, closely coiled hair which marked them off from the Scandinavians with slightly pigmented skin, blue eyes, narrow nose and straight hair; also from the yellow-skinned, black-eyed Chinese with their small, almost bridgeless noses and from the inhabitants of the Hawaiian Islands, of great stature, light, but easily bronzed skin, wavy hair and high-bridged nose.

To-day, things are much changed. Into the Hawaiian Islands, for example, have been brought Chinese, Japanese, Filipinos, Portuguese, English and other races, who have intermingled with the Polynesians until pure-blooded representatives of the latter are becoming scarce. The race of North American Indians has for three centuries been in contact with European stocks and in these United States few of them are left of pure blood. Central Africa is being penetrated by Europeans, as it has been for centuries by Arabians and Jews, and it will be only a few score years before pure representatives of the Negro race also will be hard to find. The Negroes which were imported to the Americas have largely hybridized with the whites and Indians. The standard races of mankind are rapidly disintegrating. For race implies a certain amount of isolation under cover of which it can develop, but in these days of rapid transportation to all parts of the globe isolation is no longer possible.

Those who look to the future are naturally concerned with the question: What is to be the consequence of this racial intermingling? Especially we of the white race, proud of its achievement in the past, are eagerly questioning the consequences of mixing our blood with that of other races who have made less advancement in science and the arts. Is it possible to predict the consequences of such racial intermingling? Is there any reason for thinking that hybridization, such as is going on even among the races of Europe, leads to an inferiority of the offspring?

To-day, as never before, we are in a position to make investigations that may throw light upon this subject. First, because racial intermingling is so widely occurring and, secondly, because the technique of the study of race crossing has been worked out by the geneticists,

[1] Address delivered in April, 1928, at the Carnegie Institution of Washington, Washington, D. C.

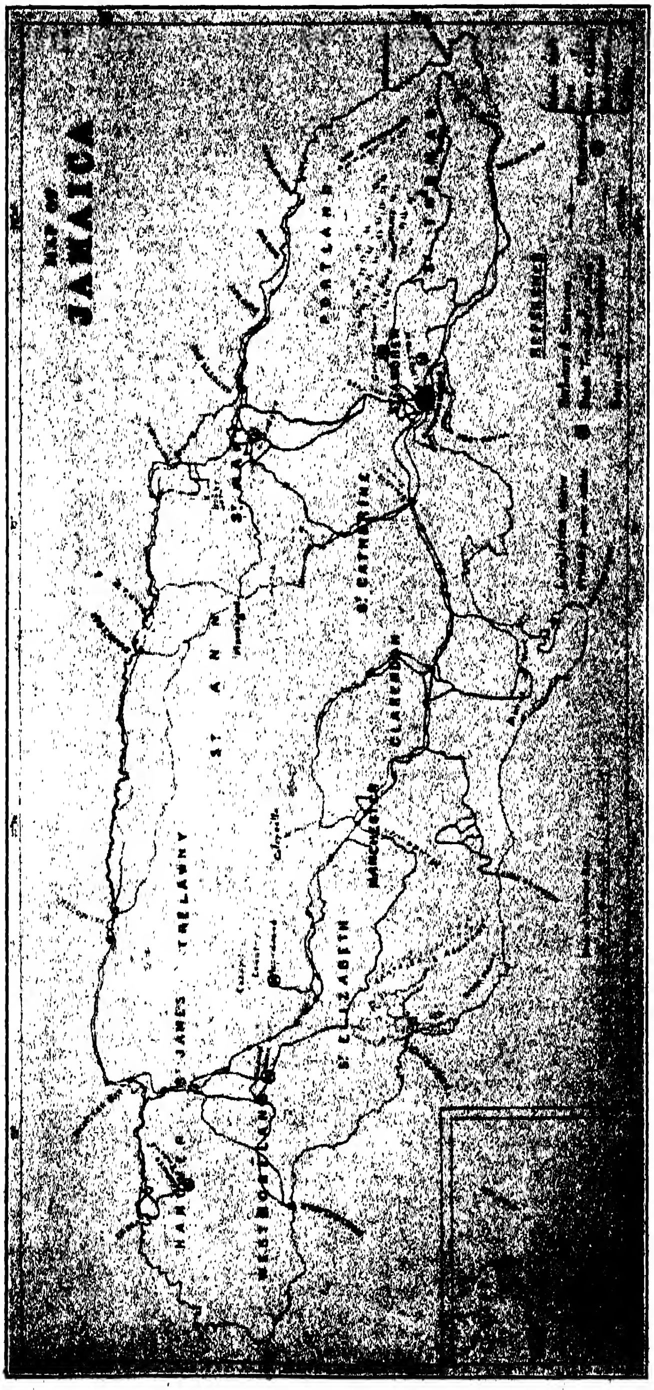


FIG. 1. MAP OF JAMAICA
SHOWING PLACES WHERE POPULATION WAS EXAMINED.

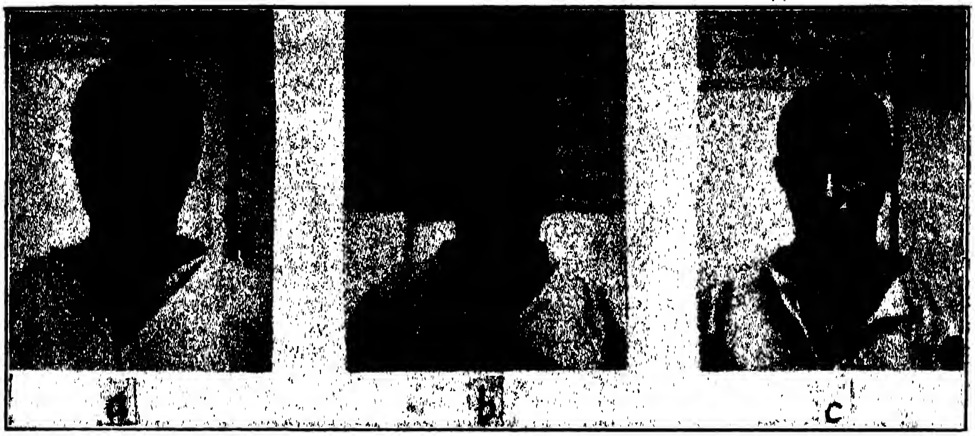


FIG. 2. a, b, NEGRO FACES; c, FACE OF A BROWN (MULATTO)

proceeding along experimental lines. The unexampled progress in the study of heredity in the last twenty-five years is due to systematic experiments in crossing of distinct races and studying the distribution of the racial traits in the first, second, third and later generations following the cross.

Genetical experimentation in hybridization has revealed several general principles. One is the fact that the inheritable traits do not ordinarily permanently blend in the offspring, but some of them tend to recur in their pristine purity in later generations. The principle of segregation of traits has become well established. It is recognized, however, that such segregation is the more obvious and the more complete the simpler the genetic constitution of the trait in question. If the trait is composite, composed of two or more elements, then segregation is less clear and the course of inheritance is, in general, complicated and sometimes "blending."

Another principle that has been established is that of heterosis or the hybrid vigor observed in the first generation in the offspring of a hybrid mating. This is best seen in the first generation, but its consequences are found scattered among individuals in later generations. A familiar example of such hybrid vigor is the mule, which is more vigorous than either of the parental species involved.

Still another principle observed in some cases is that of diminished efficiency of certain hybrids, owing to a conflict of instincts. Such dog-hybrids as that resulting from a cross between a collie and a terrier, or hybrids of poultry between an egg-laying and a periodically broody strain are of little value. In these cases the hybrids have lost the remarkable and valuable sets of instincts that have been built up through generations of careful breeding and are markedly inferior to either of the highly bred parental stocks.

In order to make a comparative study of the efficiency of a hybrid race and the two parental stocks from which it was derived the Carnegie Institution of Washington accepted a gift made to it and undertook a study of the topic of Negro-white crosses in the island of Jamaica, British West Indies.

The island of Jamaica (Fig. 1) is particularly well adapted to such a study, partly because there still exists a fair proportion of pure-blooded representatives of both the white and the Negro races, as well as a large number of hybrids between these races. The population speaks English and is socially so well organized as to be readily accessible

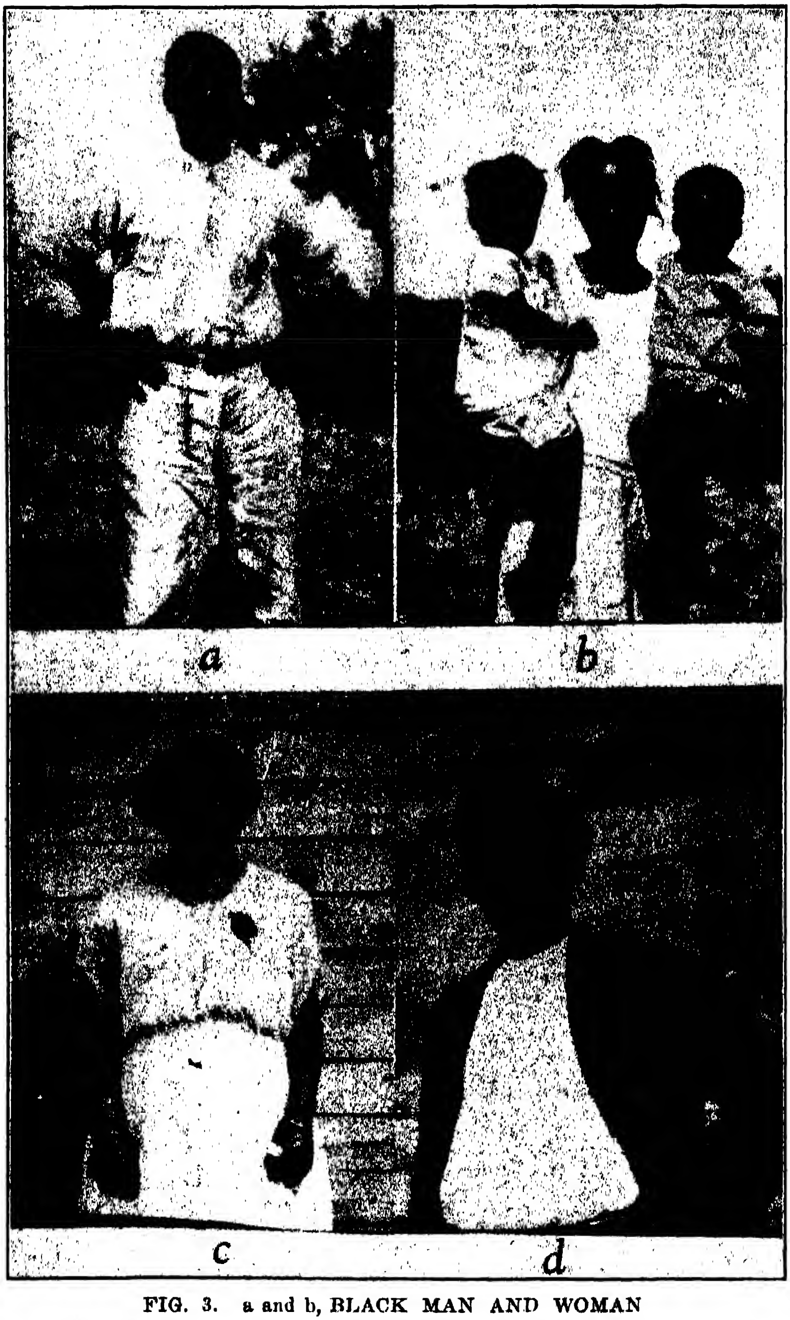
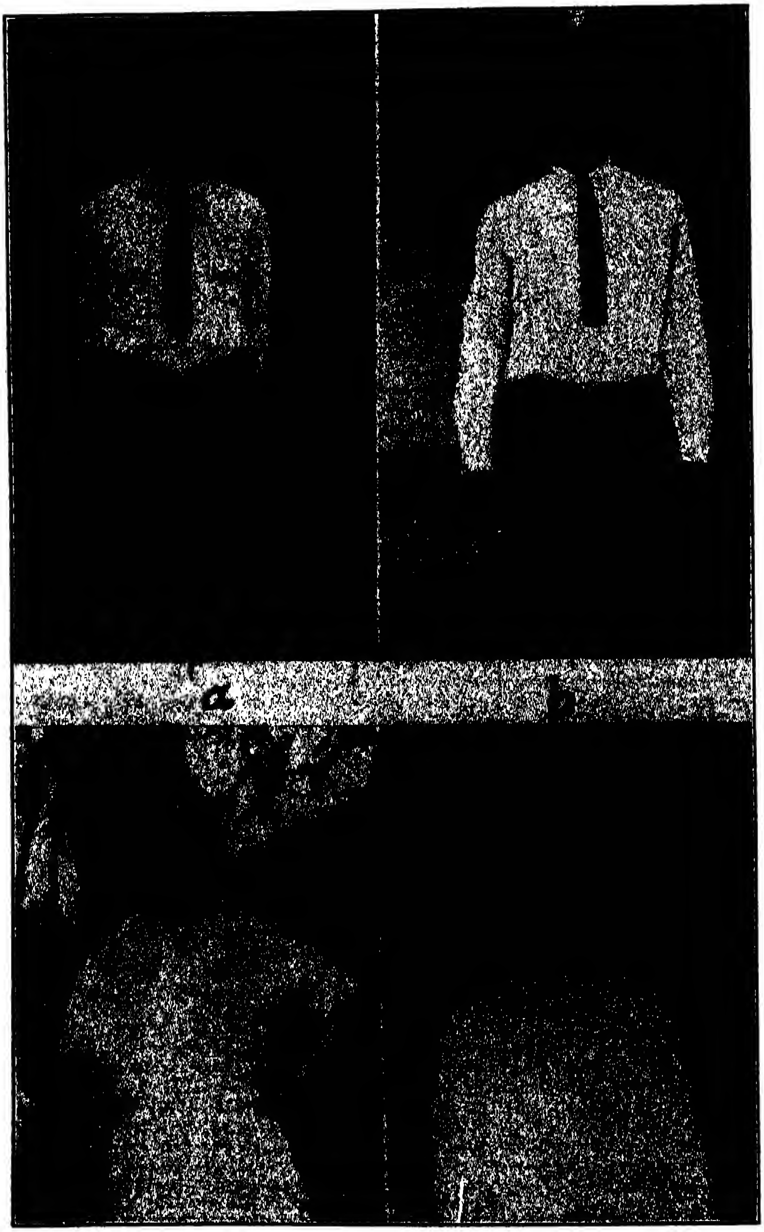


FIG. 3. a and b, BLACK MAN AND WOMAN FROM THE MAROON TOWN OF ACCOMPONG. NOTE FACIAL FEATURES, HAIR, DISTANCE BETWEEN EYES.

c and d, BLACK MAN AND WOMAN OF GORDON-TOWN, AN AGRICULTURAL COMMUNITY NEAR JAMAICA.

FIG. 4. EXAMPLES OF THE WHITE POPULATION OF SEAFORD TOWN
a, b, MAN AND WIFE. NOTE SHORT INTEROCULAR DISTANCE, LONG NARROW NOSE. c, SON OF MAN AND WIFE, ABOVE. d, e, SISTERS, SHOWING RESEMBLANCE CHARACTERISTIC OF AN INBRED COMMUNITY.



c d

FIG. 5. a, b, TWO GRAND CAYMAN ISLANDERS
NOTE TALL STATURE, NARROW FACE, LONG SLENDER NOSE.

c, d, TWO BROWNS
c, MARKET WOMAN OF GORDON-TOWN; d, STUDENT AT MICO COLLEGE.

to the investigation. We were fortunate in being able to put the work of collecting data into the hands of Mr. Morris Steggerda, who proved himself excellently fitted for the work. To carry out the program of the committee in charge of the investigation it was necessary to study carefully one hundred full-blooded Negroes—male and female—called hereafter "Blacks"; one hundred white people and one hundred mixtures between the two races—whom we may call Browns. To make the two groups comparable it was necessary to take them, as far as possible, from the same social stratum.

It was fairly easy to find full-blooded Blacks, especially in the so-called Maroon towns, such as Accompong in the West (Figs. 1; 3, a, b), to which the Negro slaves retreated many generations ago when the English seized the island from the Spanish. Many are found in farming communities of the island whose whole appearance supports their contention that they are of pure African stock (Fig. 2, c, d).

It was much more difficult to find persons of unmixed white stock living as agriculturalists in an island composed of 98 per cent. colored persons. Fortunately for our study, there is a group of Germans whose ancestors were brought to this island about four or five generations ago and which is now living at Seaford Town in the west center. This is an isolated white community, who have carefully preserved their genealogical records (Fig. 4).

But we were not able to get enough adult whites at Seaford Town, and so studies were made at Grand Cayman Island, a two days' sail to the westward of Jamaica. Here is a group of whites of English stock, rather taller than the German folk of Seaford Town (Fig. 5, a, b).

Brown (or hybrid) people it was easy to get in the required number. Some of these were agriculturalists at Gordon Town near Kingston (St. Andrew) and elsewhere (Fig. 5, c). Rather more than were desirable were studied at the training schools for teachers—both those for men and those for women—for these brought into the statistics a lot of non-agricultural people (Fig. 5, d).

Studies were made also on children; both babies at the creches, or day nurseries in Kingston, and school children from eight to sixteen years of age. The open-air schools that abound in the island offered good shelter and excellent light for the measurements and tests.

The results of this study have now been brought together.

One of the first questions raised in the study of race mixtures is that of variability. This question is of particular interest at the present moment through the circumstance that Dr. M. J. Herskovits, who has studied many Negroes in the United States, has reached the conclusion that they show a reduced variability, as compared with the white. This is opposed to the expectation, based upon genetical experimentation, that in the second hybrid generation there is increased variability. This increased variability is found, however, only when the original races are of very pure stock. Also, the increased variability is found just in those traits in which the original stocks differ. Moreover, if there are many of such dissimilar traits, the hybrids may differ from each other in presenting new combinations of such traits.

As stated, Herskovits has found that the Negro mixtures are not, in general, highly variable. For example, he has shown that they are not more, but less, variable in stature than a lot of whites measured in different parts of the country. This, however, is not to be wondered at because, on the average, the Negroes and the whites of the United States have the same stature. Variability comes about when the racial traits differ by at least one gene. Under those circumstances the offspring may

possess, or lack, the gene and, accordingly, may possess, or lack, the trait whose development depends on that gene. Now there is no reason for supposing that there is any difference in the genes that are responsible for the stature of the average white and the average Negro, or if there are differences in the genes they do not affect stature as a whole but merely elements which go to its make-up. In studying variability of hybrids we must focus attention upon traits in which the original races differ by one or more genes.

Gene differences between races are recognized as such partly by an important difference in mean size of the trait and partly by the behavior of the trait in hybridization. If we consider the breadth of the nose we have a trait which is genetically different in the white and Negro races. The hybrids

TABLE A

PROPORTIONAL DISTRIBUTIONS OF NASAL BREADTH IN THE THREE GROUPS

The different classes of nose width are given in the first column; in the successive column, left to right, the proportion of each racial group that has a nose of the class of width named in left hand column

Class mm	Whites percentage	Browns percentage	Blacks percentage
30–32	16.0	....	....
33–35	48.0	1.1	....
36–38	26.0	9.7	....
39–41	10.0	26.9	5.9
42–44	.....	35.5	23.5
45–47	......	18.3	45.1
48–50	....	1.5	21.6
51–53	......	1.1	3.9
Mean and probable error	34.90 ± 0.24	42.61 ± 0.24	45.82 ± 0.26
Standard deviation and probable error	2.56 ± 0.17	3.44 ± 0.17	2.75 ± 0.18

have a nose which is intermediate in breadth (Fig. 2, c) and in later generations, indeed, in a mixed Negro population, we find a very great variability in nose breadth, as shown in Table A. An examination of this table shows that the variability of the browns, as the hybrids are called, is distinctly greater than that of the whites and blacks, as the coefficient of variability which is used as a measure of such variability shows. There are no broad-nosed whites and no narrow-nosed blacks, but the browns range all the way from narrow noses to broad noses.

Another distinguishing genetical trait is that of form of the hair, as measured by the diameter of the curl. This is, as every one knows, very small in the case of the Negroes (Fig. 2, a); very great in the case of the whites, a large proportion of whom, indeed, have no measurable curl in the hair. The browns are intermediate in respect to hair form (Fig. 5, d). The variability of this hair form, as measured by the coefficient of variation, is seen to be 50 per cent. greater in the blacks than in the whites.

Similarly, in skin color the offspring of two mulatto parents may run the whole gamut from a white skin to an ebony black, like that of the Negro ancestor. The range in variation of skin color in such hybrids is, indeed, very great.

We conclude, accordingly, that in human hybrids, as in other animal hybrids, variability of the hybrids is a widespread phenomenon, especially that those traits that are different in the parental stocks vary in the descendants. In those cases where such extraordinary variability is not found in the hybrids the conclusion is supported that the parental stocks were not themselves pure, or else that the trait depends upon a large number of genes, or that there has been selective mating, tending to eliminate variability.

We have studied about thirty physical traits in the three groups. In some of these the Negroes and whites differ so greatly that it is quite certain that distinct genes are involved. Thus the races differ in length of arm-span and leg (Fig. 6), which are both greater in the

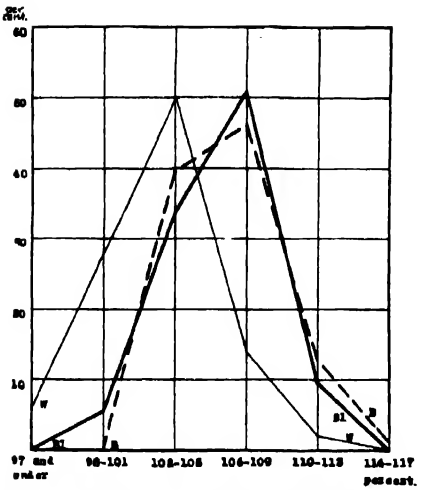


FIG. 6. GRAPHS SHOWING DISTRIBUTIONS OF SPAN ÷ STATURE FOR MALE WHITES (FINE LINE), BROWNS (BROKEN LINE) AND BLACKS (HEAVY, CONTINUOUS LINE). NOTE THE RELATIVELY SHORT ARMS OF THE WHITES. THE BROWN CURVE HAS A BROAD PEAK, COVERING BOTH PEAKS OF THE PURER RACES.

Negro than in the white. The breadth of the pelvis (Fig. 7) is much less in the Negro. The lower arm constitutes a relatively greater fraction of the entire arm in the Negro. The Negro's head is longer, but not broader or higher. The distance between the pupils is much greater than in the whites (Fig. 3, d). The feet and hands are longer in the blacks. The outer ear is not so long. There are fewer hairs developed on hand, arm and leg, and such as there are are short (Fig. 8). The internal impulses that direct development are very different in the two races.

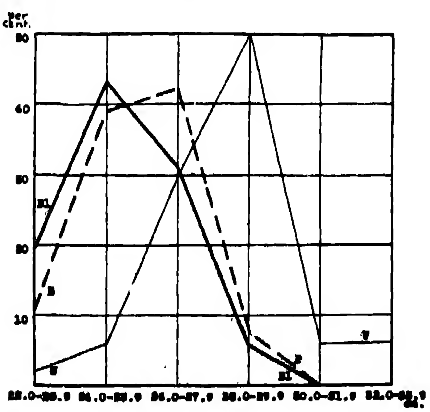


FIG. 7. GRAPHS SHOWING DISTRIBUTION OF INTERCRISTAL (PELVIC) BREADTH (IN CENTIMETERS) FOR MALE WHITES (FINE LINE), BROWNS (BROKEN LINE) AND BLACKS (HEAVY, CONTINUOUS LINE). NOTE THE RELATIVELY SMALL PELVIC BREADTH OF THE BLACKS. THE DISTRIBUTION IN CASE OF THE BROWNS FORMS A BROAD PEAK EXTENDING FROM THE PEAK OF THE BLACKS AND REACHING TOWARD THAT OF THE WHITES.

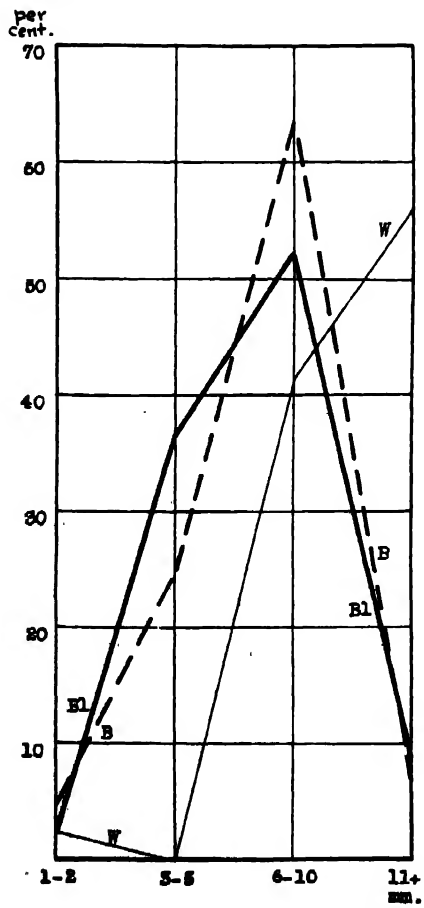


FIG. 8. GRAPHS SHOWING DISTRIBUTION OF AVERAGE LENGTHS OF HAIR ON ARMS IN DIFFERENT INDIVIDUALS OF THE 3 RACIAL GROUPS: WHITES (FINE LINE), BROWNS (BROKEN LINE) AND BLACKS (HEAVY, CONTINUOUS LINE). THE COMMONEST GRADE OF THE WHITES IS ONE ATTAINED BY FEW BLACKS OR BROWNS.

In the matter of hybrid vigor very little evidence was obtainable from the studies made in Jamaica. The most aberrant individual in size that we met was a huge woman over six feet tall. We could not be sure that she is a hybrid. This extreme case, however, was no doubt due to a pituitary disturbance, and pituitary disturbances may sometimes be due to a disharmony introduced by hybridization. On the average, however, the browns do not differ from the blacks in height and weight.

It is in the fields of the physiology and psychology that the relation of hybrids to parental stocks has the greatest social importance. In the matter of tooth decay, whose social importance is now becoming recognized on account of its relation to general health, we find a clear difference between the Negroes and the whites, in that the Negroes show a smaller amount of decay. The index of decay in the Negroes is 3.4 and in the whites 4. The browns show, indeed, a still slightly smaller average of defect, although the difference between the browns and blacks is less than the probable error. The condition in the browns is much more variable than in the blacks. The superiority of the browns is probably due to the inclusion of a considerable number of men from Mico College, young men who have been especially trained in the care of their bodies. Of the 21 per cent. of young brown males that showed no tooth decay about three quarters are from Mico College. Apart from such persons the distribution of tooth decay in browns is not very different from that of the whites.

Interesting differences between the blacks and the whites appear in their ability to make fine discriminations in the elements of musical capacity, as measured by the Seashore test. Thus the grades obtained in discrimination of pitch by the blacks are measured, on the average, by the score of 75, whereas the whites received the score of 71 and the browns the score of 77, being very close to that of the blacks. Indeed, nearly 30 per cent. of the browns received below 50 per cent. in pitch discrimination, as opposed to only 10 per cent. of the whites and 19 per cent. of the blacks. We see, then, that the blacks discriminate pitch better than the whites and that the browns are very variable, and a larger proportion of them than the whites, even, are unable to make any but the crudest discriminations.

In the matter of rhythm, also, the blacks are far superior to the whites, scoring an average of 86 to the whites' 78. The browns show a great range of scoring from 50 to 100 (Fig. 9). There is a larger percentage of the browns in the highest group than in the whites, but, conversely, in the lowest groups there are found many more browns than blacks, so that the brown group is characterized by including many persons who show very poor, as well as many who

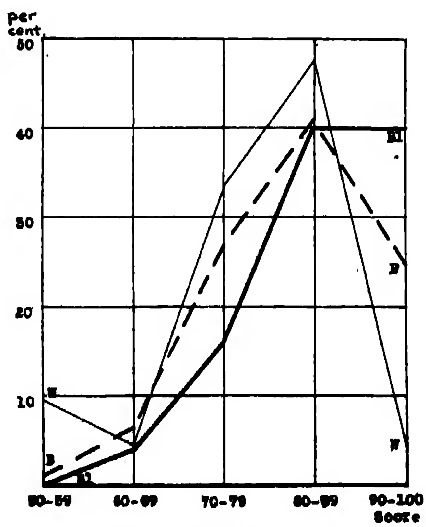


FIG. 9. GRAPHS SHOWING DISTRIBUTION OF SCORES OR GRADES OBTAINED IN THE SEASHORE TEST FOR RHYTHM IN MUSIC, IN 3 RACIAL GROUPS: WHITES (FINE LINE), BROWNS (BROKEN LINE) AND BLACKS (HEAVY, CONTINUOUS LINE). THE GREAT PREDOMINANCE OF BLACKS IN THE HIGH SCORES, AND THE VARIABILITY OF WHITES AND BROWNS ARE WELL SHOWN.

show very good appreciation of differences in rhythm.

For more strictly intellectual tests certain performance operations were carried out. Thus in the cube imitation test in which the subject has to reproduce a certain more or less complicated sequence of movements of the examiner the blacks get a score of 4½, as contrasted with that of 6½ obtained by the whites. The whites do, therefore, nearly 50 per cent. more of the test correctly than do the blacks. The browns are nearly intermediate in their efficiency in this test, although they lie somewhat closer to the blacks than to the whites.

In the matter of drawing a man, without "copy," the whites did best, while the blacks were not inferior to the browns (Fig. 10).

Another test employed was that of putting together six pieces of wood on which were drawn the parts of a man. These were to be placed so as to reconstruct the image of a man. The blacks took longer to make the reconstruction than the whites. Thus, on the average, blacks took forty-three seconds, as contrasted with twenty-six seconds required by the whites. The browns are intermediate but much closer to the blacks than to the whites in this capacity, and, as measured by the standard deviation, their scores were the most variable. But more of the browns failed to finish the test (over ninety seconds) than of the blacks (Fig. 11).

Another test applied was the so-called Knox moron test, consisting of a board with a hole into which were to be placed blocks of different form so as completely to fill the hole. The blacks, on the average, took 119 seconds to perform this test; the whites 87 seconds and the browns 113 seconds. Thus, again, the browns were intermediate and closer to the blacks than to the whites. This is a test which involves a good deal of imagery, some foresight, planning and ability to make use of past experiences

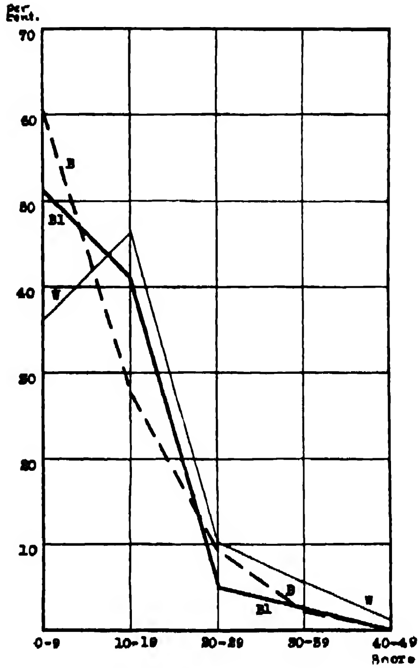


FIG. 10. GRAPHS SHOWING DISTRIBUTION OF SCORES OR GRADES OBTAINED IN THE DRAWING OF A MAN BY THE 3 RACIAL GROUPS, MALES AND FEMALES COMBINED: WHITES (FINE LINE), BROWNS (BROKEN LINE) AND BLACKS (CONTINUOUS, HEAVY LINE). THE WHITES HAVE FEWEST FAILURES (0–9) AND SHOW A LARGER PERCENTAGE IN ALL THE HIGHER SCORES THAN ANY OTHER GROUP. NOTE THE LARGE PROPORTION OF FAILURES AMONG THE BROWNS.

and this group of traits seemed to inhere in the whites of Jamaica more than in the blacks.

The Army Alpha tests of intelligence were used with some interesting results. Thus the second test is that of ability to make simple arithmetical computations. Simple questions were asked, like this: How many are 60 guns and 5 guns? More complicated questions were of this nature. A rectangular bin holds 200 cubic feet of lime. If the bin is 6′ long and 10′ wide, how deep is it? In this arithmetical test the adult blacks did better than the whites, scoring, on the average, 10 correct out of a total of 20, whereas the whites scored only 7½. The

browns scored 8.4 and thus were intermediate in their performance between the blacks and whites.

Another test in the Army Alpha is No. 3—a test of common sense. The question is asked, for example, "Why do we use stoves?" and suggested answers are "because they look well"; "they keep us warm"; "they are black." The subject is to check the appropriate answer. Now in this exercise of common sense the blacks were clearly inferior to the whites, since they scored less than 6 right out of 16, while the whites averaged 8½ right. The browns, on the other hand, scored only about 5 correct, being inferior in this respect to either the Negroes or the whites. A summary of the results of the Army Alpha tests is shown in Table B.

group who are incapable of making any progress at all with the task before them. We have seen this in the cube imitation test, where 7 per cent. of the browns get the poorest score, as contrasted with 3 per cent. of the blacks and none of the whites. We have seen it again in the time required to put together the manikins in which 5 per cent. of the browns surpassed the limit of one and a half minutes; only 3 per cent. of the blacks and 2 per cent. of the whites (Fig. 11). Repeatedly the scores of the browns are characterized by this phenomenon. An exceptional number show complete failures; a fairly large proportion of persons are as competent in the task as the whites. The reason why the browns are intermediate between the blacks and the whites, or below either, is because of this large burden of ineffective persons who seem to be muddle-headed or incapable of collecting themselves to do the task in hand. One gets the impression that the blacks may have on the average the inferior capacity but are able to use what they have. The browns, as a whole, have a superior capacity to the blacks, but there is a much larger proportion of them who through becoming rattled or through general muddleness are unable to make any score; while, on the other hand, a large number do brilliant work.

TABLE B

SUMMARY OF MEAN SCORES OBTAINED IN THE EIGHT ARMY ALPHA TESTS

	I	II	III	IV	V	VI	VII	VIII	Avg.
Black	*5.9*	*10.0*	5.9	15.8	8.8	*7.2*	*13.9*	9.6	9.64
Brown	5.1	8.4	5.2	12.7	6.4	5.6	10.8	9.4	*7.95*
White	4.9	7.5	*8.5*	*20.3*	*11.4*	6.8	10.2	*12.2*	*10.23*

This reveals the fact that, considering all tests together, the whites do better than the blacks, on the average, despite the fact that in respect to some of the tests the blacks are slightly superior to the whites. The browns, on the average, are inferior to either the blacks or whites.

If we consider the relative standing of the three groups at different ages we reach a somewhat surprising result, namely, that the children of ten to thirteen years do better in the brown group than in either black or white. The children of thirteen to sixteen years also are superior in the browns, but in the adults, as stated, the browns are clearly inferior to either of the parental stocks. Apparently the browns mature earlier (possibly an evidence of hybrid vigor), but their development stops earlier.

This inefficiency of the adult browns depends upon the presence of an excessively large number of persons in that

This result serves to explain a difference of point of view of persons who have written about mulattoes. It is insisted by some that mulattoes are superior to the blacks in mental capacity. Others stress their unreliability, untrustworthiness, general inefficiency. The group who stress their superiority refer to such eminent citizens as Booker T.

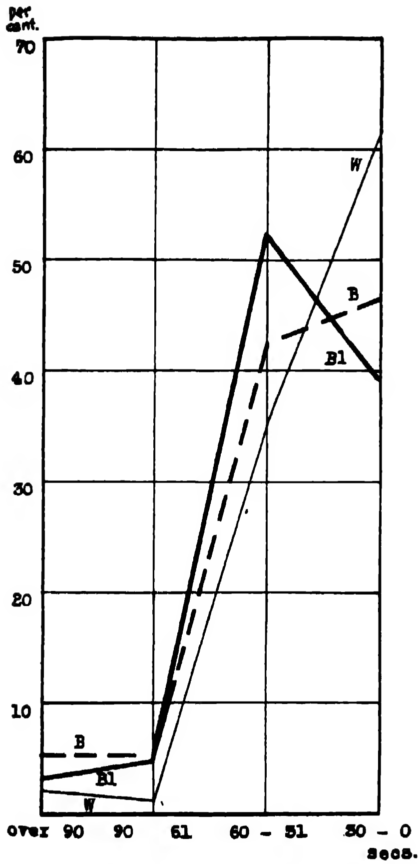


FIG. 11. GRAPH SHOWING DISTRIBUTION OF TIMES REQUIRED TO PUT TOGETHER THE PARTS OF THE MANIKIN BY 3 RACIAL GROUPS, MALES AND FEMALES COMBINED: WHITE (FINE LINE), BROWN (BROKEN LINE), BLACK (CONTINUOUS, HEAVY LINE). NOTE THAT THE WHITES DO BEST IN THE SHORT-TIME CATEGORIES (0-30 SECS.). A LARGER PROPORTION OF THE BROWNS (B) FAIL TO PUT THE MANIKIN TOGETHER (OVER 90 SECS.) THAN OF THE BLACKS (B1).

Washington, Frederick Douglass, Dr. DuBois. Those who stress their inefficiency see the other end of the series—the people who, apparently through mental conflicts, are extraordinarily ineffective. This, then, is one of the results of hybridization between whites and Negroes—the production of an excessive number of ineffective, because disharmoniously put together, people. A list of the traits has been prepared in which the browns are clearly inferior, on the average, to blacks and whites. This includes the ability to draw a man, without a model to copy. Such a task involves imagery and organization in which the browns seem, on the average, to be inferior. Again, they are inferior in the form substitution test in which one writes an appropriate figure in each of some five or six different form symbols many times repeated. The browns make more errors in assigning the proper figures to the symbols than do the blacks, although, on the average, they attempt rather more of the substitutions. In four of the eight Army Alpha tests the browns seem to be inferior to both the blacks and whites. These are all important tests of mentality and lead to the conclusion that, on the average, the browns are frequently inferior in mental tests, while they show more extremes of excellent and poor performance than the other groups. The only mental tests in which the browns are superior to either blacks and whites are certain exercises done by children between the ages of ten to sixteen years. This fact again illustrates the precocious development of mentality in the brown child. Also, the adult browns were superior in repeating a given series of figures.

The application of the results of the study of Negroes, whites and hybrids between them in Jamaica leads to the conclusion that physically there is little to choose between the three groups, although, on the whole, the Negro makes the better animal and, especially, is provided with better sense organs. The browns show much greater variability and, indeed, are put together differently from the average whites and blacks. Thus, whereas the whites are characterized by relatively short legs and long body and the blacks by relatively long legs and short body, some of the mulattoes have an unexpected combination of

long legs and long body and others of short legs and short body. Also, while there is a high degree of correlation between leg length and arm length, some of the hybrids are characterized by the long legs of the Negro and the short arms of the white, which would put them at a disadvantage in picking up things from the ground.

But in regard to intellectual traits the conclusions are different. The browns show great variability in performance. They comprise an exceptionally large number of persons who are poorer than the poorest of the Negroes or the poorest of the whites. On the other hand, they show some individuals of a high intellectual quality. The average of the performance of the browns is generally somewhat better than that of the Negroes. It is, however, this burden of ineffectiveness which is the heavy price that is paid for hybridization. A population of hybrids will be a population carrying an excessively large number of intellectually incompetent persons. On the other hand, a population composed of hybrids between whites and Negroes will contain persons better endowed in appreciation of music and in simple arithmetical or mental computations, as well as more resistant to certain groups of diseases, than a pure white population. If only society had the force to eliminate the lower half of a hybrid population, then the remaining upper half of the hybrid population might be a clear advantage to the population as a whole, at least so far as physical and sensory accomplishments go.

The person who seeks to secure the racial improvement of any species has only two courses open to him: Either to await new mutations in the race which he wishes to improve, or else to cross it with some other race that already has the quality he desires.

Thus the English race, which is poorly endowed with musical capacity, could get that capacity by mingling with the Negro.

The difficulty in waiting for the desired mutation to arise in the race is that it is a slow method. The method of hybridization has the difficulty that it introduces other, undesired traits into the complex. Of course, by controlled selective breeding the undesired traits can be bred out, while the desired traits are retained.

But we have no such control of human matings as is demanded if success is to follow the method of improvement by race crossing. It seems hardly applicable to mankind.

Moreover, quality of performance is not the only test of ability to play a part in society. There exists in mankind a strong instinct for homogeneity. Even children tend to mock at the cripple or deformed person. A homogeneous group of white people will always be led by its instincts to segregate itself from Negroes, Chinese and other groups that are morphologically dissimilar from themselves. We should consider the psychological, instinctive basis of this feeling. It is not sufficient merely to denounce it. It probably has a deep biological meaning and so long as it exists, so long we should be led to follow it as a guide if we are to seek to establish a commonwealth characterized by peace and unity of ideals.

THE GOBIES OF THE GULF OF GUINEA

By Professor A. S. PEARSE
DUKE UNIVERSITY

ALONG the coast of Nigeria ramparts of land cut off long strips of water from the ocean. These lagoons receive fresh water from the mighty Niger and many smaller streams. They parallel the coast and serve as safe highways for the patch-sailed dug-out canoes of the native fishermen and traders. The water is so shallow that when the wind fails, boats are easily poled about. Mangroves flourish in such situations, and there are hundreds of miles of these fantastic plants. Among their branches are strange birds and agile monkeys; on their roots are crabs and — most wonderful climbing fishes! I write of the last, which the British in Nigeria call mud fishes.

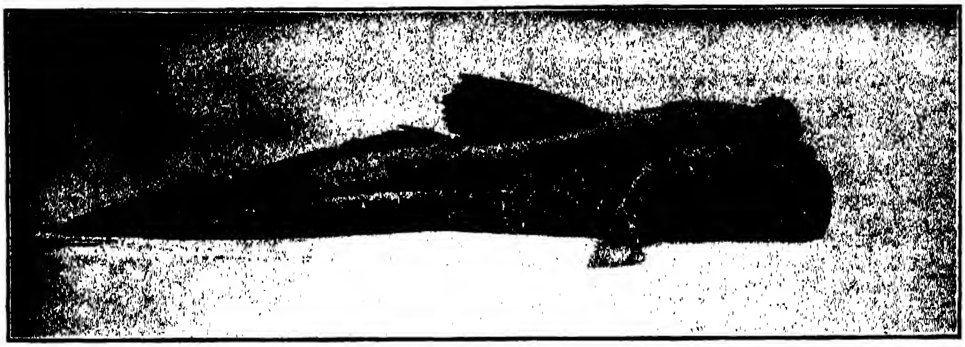
If one takes a lazy canoe journey through the estuary of a small stream, he sees mud fishes everywhere. They skip over the flats and hide in the grass as the canoe approaches. They leap from a near root, take a few skips on the surface of the water and climb quickly up a far root. From this point of vantage they roll their eyes at strange intruders. If cornered, a mud fish may, with apparent reluctance, take to the open water and swim laboriously, with its nose and eyes above the surface. As a last resort, it may even dive some distance under the water.

Occasionally a mud fish may sit stolidly on his root and allow a boat to approach quite closely. The canoe bumps his root, and still he sits motionless. I stretch out my hand, thinking perhaps he is asleep, but when the hand is six inches away he gives a flip of his tail and skips over the water into an inaccessible tangle of roots.

A naturalist who sees a mud fish is of course filled with a desire to collect the beast and take its picture. My native "boy," Rufus, captured several specimens by chasing them into crab holes and reaching down into the muck with his hand. After hours of patient, stealthy effort, we took pictures, most of them worthless, but a few fairly good.

Mr. J. T. Nichols has been kind enough to identify the Nigerian mud fish as *Periophthalmus koelreuteri*. Among climbing fishes this is a rather large species, as it often attains a length of more than six inches. It is one of the gobies, which are a widely distributed family. In Europe gobies are ordinary stream fishes. In Hawaii there is a species which adheres to rocks in swift mountain streams with a sucker which is formed by a pair of fins. Along the shores of the Pacific Islands certain species are beach skippers. A large skipper hops about on the mud flats at Guam and dodges into crab holes when pursued. In the Philippines small gobies tug worms out of the mud in the intertidal zone; for all the world like robins extracting earthworms from a lawn. About the mouths of Siamese rivers there is a mud fish which makes burrows that extend down to a depth of three or four feet.

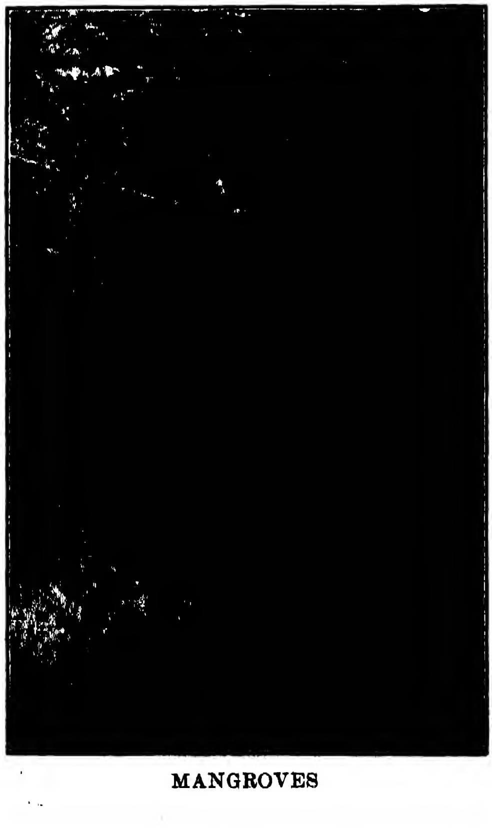
When one sits for hours on the hard bottom of a dug-out canoe, with nothing to do except watch for mud fishes and occasional monkeys, at the same time keeping a subconscious vigil over his back and the under sides of his legs for tse-tse flies, he has time for thought. And he thinks—even in sultry, somnolent Nigeria. I thought of the ocean as the first home of life and of the gradual invasion through the ages of land and freshwater habitats. This is perhaps



THE MUD FISH, *PERIOPHTHALMUS KOELREUTERI*

one of the most exciting chapters in the book of natural history. Many groups of animals have had abundant opportunities to attain the ability to breathe air and thus take up life on land, but only three have met with any degree of success—snails, arthropods (crabs, insects, spiders, etc.), and vertebrates.

Land animals have the advantage of living in the atmosphere which, as it is less dense than water, permits more rapid movement. Speed is also favored by the fact that more oxygen, which is through oxidation the basis of all animal activity, is more abundant in air than in water. The disadvantages that accompany land life are the seasonal fluctuations in available food, the rapid and extensive changes in temperature, and the danger of loss of water from the bodies of animals, by drying out. It is on the whole true that the quicker land animals which live in more variable environment have in many instances a higher degree of psychological development. The opportunity to move fast has been associated with the development of sense organs which could perceive objects and conditions more accurately at a distance. It is much more necessary for an automobile which travels at sixty miles per hour to have an unobstructed view and accurate control than it is for a canal boat which loafs along at three miles per hour. The variable environment that land animals entered when they left the ocean put a premium on astuteness. An animal that had a harder struggle to live was obliged to have more expedients for meeting unfavorable changes in its environment. Through the ages, land animals have established



MANGROVES

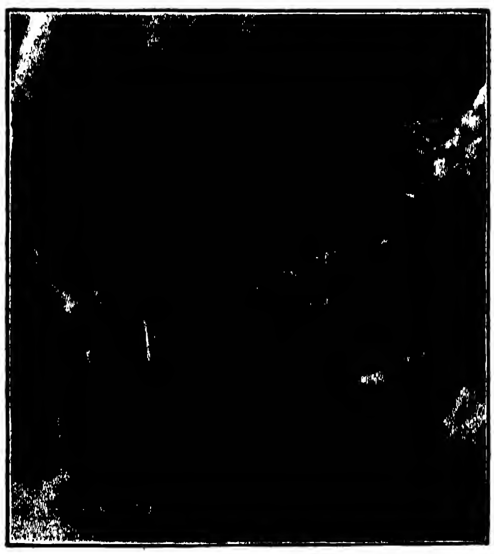
types which are wiser than their more primitive relatives in water habitats. The reward for struggling to land has been greater wisdom, with the ability to live faster and, in a sense, on a higher plane from day to day.

In their past migration from sea to land animals have taken perhaps three or four routes. Certain land crabs and some other crustaceans probably went directly to land through the intertidal zone. At the present time there are species which show varying degrees of adjustment to land life. Fiddler crabs carry sea water in their gill chambers and spend long periods out of water. The ghost crabs do not carry sea water with them, but visit the ocean frequently to wet their gills. The cocoanut crab has rudimentary gills and lungs which have developed as pouches from the gill chambers. It visits the ocean only once a year, when it returns to its ancestral home and leaves its offspring to spend a few days as water animals. Some sand-hoppers live on land but can not endure freshwater and quickly die in it.

The lung fishes which live to-day, and probably the ancestors of modern land vertebrates, are believed to have been forced to take up land life by aridity. They first invaded freshwater and became adapted to swampy situations. Then during long dry periods, they gradually became adjusted to land. Barrell says lung breathing is "an adaption which has been forced repeatedly on fishes by the recurrence of an unfavorable environment rather than one assumed within a constant environment because of inherent advantages." It was probably not so much the lure of abundant oxygen as the drying up of aquatic habitats which caused vertebrates to take up land life.

Another route from sea to land appears to have been through initial adjustment to swamp or marsh life and

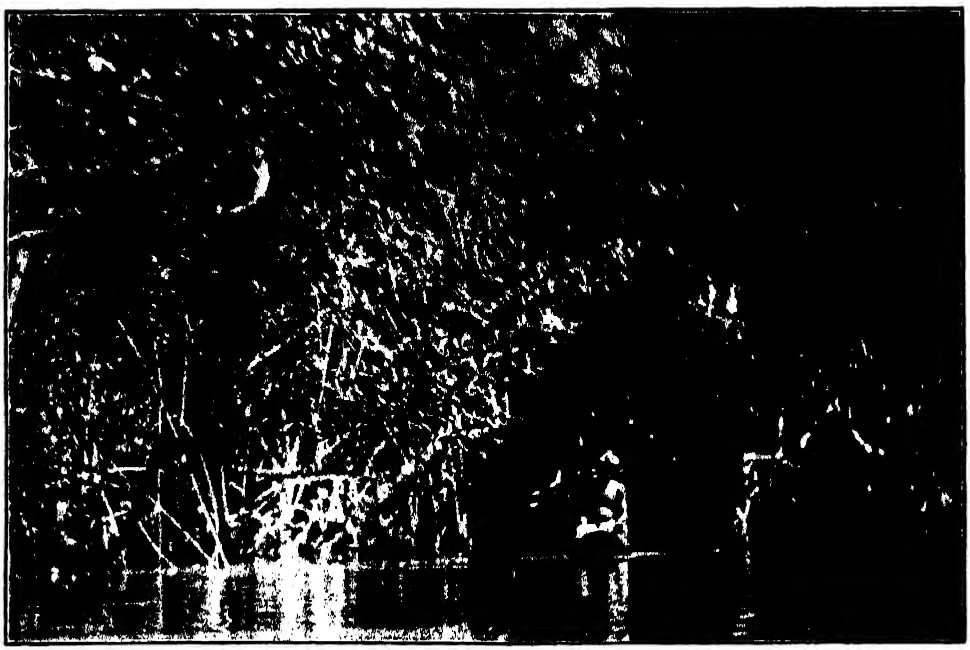
RESTING ON A MANGROVE ROOT



TWO GOBIES CLIMBING MANGROVE ROOTS

later adjustment to land. In this case the need of oxygen doubtless led aquatic animals to invade the atmosphere. In shallow swamps the decay of dead plants and animals with the activities of living

SEVEN GOBIES WALKING DOWN THE BEACH



IN THE MANGROVES

organisms may use up all the oxygen, so that none is present in the water. Swamp snails are generally pulmonates (air-breathing) and continually come to the surface. Some even deposit their eggs on twigs above the water. Mangroves grow on bottoms of soft, stinking muck. There is a lack of oxygen and their underground roots send up breathing rootlets which obtain oxygen from the air. In such situations crabs, snails and fishes climb up on the mangrove

roots and the fishes show some reluctance to enter the water, which may contain a lurking crocodile. In the moist Nigerian climate a mud fish appears to suffer no injury if kept overnight in a bucket without water. Some of the beach skippers of the Malayan region drown in a couple of hours if kept under water. A species of "climbing perch" in the Philippines may live as long as six days out of water.

The mud fishes along the Gulf of Guinea are, like many of their relatives in other parts of the earth, making a drive toward land. They have attained some of the acuity of vision and quickness of motion that characterizes land animals. They have pouches developed from their gill cavities which serve as lungs. Perhaps in a million or a billion years they may become proper land animals.

A GLIMPSE OF AUSTRALIA

By Professor ANDREW C. LAWSON

UNIVERSITY OF CALIFORNIA

AUSTRALIA is slightly larger than the United States, but it has only about 5 per cent. of our population. It is a pastoral and agricultural country, the early development of which, like that of California, was stimulated by a gold rush in the middle of the nineteenth century. Since the exhaustion of its placers it has had some great mining camps, such as Mount Morgan, Broken Hill, Kalgoorlie and Cloncurry, the spectacular production of which has done much to make Australia famous. But to-day the metal mining industry is in a decline. Many of the great mines are either exhausted, or, having been gutted of their bonanza ore, are no longer profitable at present wage costs, and no new discoveries of rich ore bodies are being made. Whatever discoveries may be made in the future, their exploitation will lead to the exhaustion exemplified in our own Comstock, Goldfield and Cripple Creek. Their influence on the development of Australia, though surely beneficent, will be evanescent. When metal mining has become relatively unimportant and even negligible, the pastoral and agricultural resources of the land will remain and will continue to yield up their wealth to the people.

Coal is, however, abundant in the more populous regions of the continent, and there is sufficient iron for domestic needs. Up to the end of the nineteenth century nearly all manufactured goods used by the Australians were imported, but during the first quarter of the twentieth century there has been a steady growth of the manufacturing industry, representing the efforts of a self-contained and peculiarly isolated country to supply its own needs. There is little doubt but that these efforts will be extended, and that the general manufacture of goods for home consumption will gradually be developed.

The chief commodities which Australia has to balance her long and costly list of imports are wool and wheat. The breeding of sheep to produce heavy yields of fine merino wool, and the pasturing of these on a vast scale has been Australia's great achievement and her most notable contribution to the world's economy. The acreage devoted to wheat is steadily increasing, and, notwithstanding the somewhat critical climatic conditions which prevail in the new territories being brought under the plow, it is probable that Australia will grow in importance as one of the world's granaries. In recent years there has been a large increase, also, of exports of dairy products.

A traveler's tale concerning this vast, thinly populated but vigorous country on the other side of the world is of course not to be trusted. Nevertheless, at the risk of confirming such skepticism, I propose to narrate some things concerning Australia which came to my attention during a recent journey across that continent.

I shall first sketch briefly[1] the physiography of the Australian continent, its relief, geological structure and climate, so that my readers may have a proper appreciation of the lure of the land in

[1] Most of the facts here recited are well known to Australian geologists and geographers, and this paper does not profess to be an original contribution to our knowledge of Australia but only a summary review of matters that should be better known.

A SKETCH MAP OF AUSTRALIA

which has been eventually founded a strong Anglo-Saxon commonwealth in the southern hemisphere, and know something of the difficulties that have been overcome, and have yet to be overcome, in this remarkable extension of the English-speaking people.

Compared with other continents the relief of Australia is very subdued. It may be regarded as a tableland which has been elevated somewhat at its eastern and southeastern margin. This marginal highland belt is commonly referred to as the Eastern Cordillera; and there are, indeed, some mountains in it toward the south which have an Alpine character. Of these Mount Kosciusko is the most notable, having an elevation of 7,300 feet near the boundary between Victoria and New South Wales. But by far the greater portion of the Eastern Cordillera is a dissected plateau, the residual mesas and ridges of which do not usually exceed four thousand feet in New South Wales, and half this in Queensland. The trend of this elevated belt is curved, with a pronounced convexity to the Pacific; and this convexity of the axis of uplift has determined the contour of the eastern coast of the continent.

The descent to the sea on the east side of the uplift is abrupt, while on the west side, in the concavity of the curve, there is a very gentle slope to the lower plains of central Australia. The divide for the major drainage of the continent is thus at its eastern side. The streams to the east are short and in their upper reaches flow in steep walled canyons; but as they leave these near the coast they pass into broad pleasant valleys. The intricate, and deep dissection of this uplifted margin of the continent has given rise to an extremely rugged but picturesque country; so rugged in

A RAILWAY CUT AT ZANTHUS, ON THE TRANSCONTINENTAL RAILWAY, SHOWING THE CONCRETIONARY CHARACTER OF THE SUB-SOIL UNDER THE DRY BUT WOODED CENTRAL PLAINS

New South Wales as to constitute a serious barrier to communication and transportation between the coast and the interior; so picturesque that it has become famous and has many colonies of summer homes on its commanding summits.

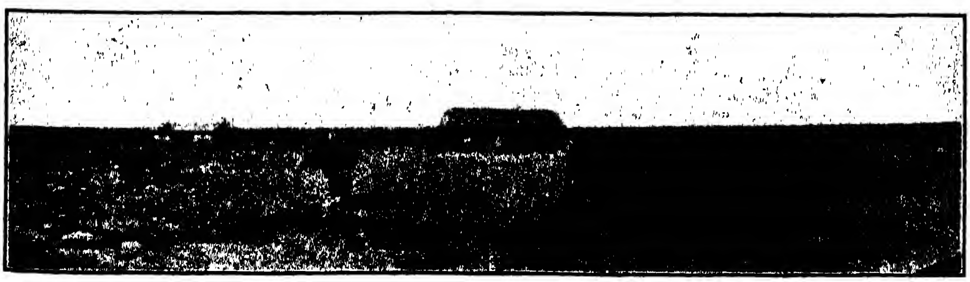
On the west of the divide are the long rivers of the continent, and these drain three hydrographic basins. The largest and most important is that to the south traversed by the Murray and its tributary, the Darling, flowing into the Southern Ocean about fifty miles from Adelaide. To the north, the hydrographic basin of the Flinders River and its tributaries drains the western slope to the Gulf of Carpentaria. Between these two lies a vast interior basin with no outlet to the sea. The chief rivers flowing from the divide into this basin are the Diamantina and Barcoo. Their waters are lost in Lake Eyre, a great desert evaporating pan partly occupied by saline residues, lying below sea level.

West of the Eastern Cordillera there are only two other portions of the continent which attain an altitude of over two thousand feet. One of these comprises the Mount Lofty, Flinders and other ranges in South Australia, extending from the southern coast near Adelaide with a meridional trend to the vicinity of Lake Eyre. The ridges which comprise this highland tract are paralleled by longitudinal valleys of depression, in two of which lie Spencer Gulf, Torrens Lake and the Gulf of St. Vincent. The highest point of the South Australian highlands is Mount Brown, which has an elevation of 3,100 feet. The other high region is in the center of the continent under the Tropic of Capricorn. Here a very considerable area, including the MacDonnell Ranges, is enclosed by the two-thousand-foot contour. All the rest of Australia, excepting the island of Tasmania, is a vast plain. Of this plain the eastern third, comprising the middle or closed hydro-

graphic basin and large parts of the southern and northern basins, is known as the Great Artesian Basin. It lies below the one-thousand-foot contour, and perhaps half of it is below five hundred feet. To the north it passes into the lowlands which encircle the Gulf of Carpentaria, which is itself a very shallow sea. The Great Artesian Basin is underlain by undisturbed Mesozoic strata which afford storage for large quantities of underground water, and this has become an important factor in the settlement and utilization of this vast arid tract.

The western two thirds of the continental plain has for the most part an altitude of from one thousand to one thousand five hundred feet. On the south it forms the coast of the Great Australian Bight, where it presents an unbroken sea-cliff for many hundreds of miles to the Southern Ocean. On the west it breaks away with a steep front to a low, narrow, coastal plain at the shores of the Indian Ocean. On the northwest side of the continent, from about latitude 28° South to the Arafura Sea, the plain drops more irregularly but gently to the coastal lowlands. The contours of the land are deeply indented, the profiles are flat and there are many embayments of the coast. The rivers draining into these embayments are almost limited to the coastal lowlands, their headwaters not reaching far into the interior continental plain. Compared with the drainage from the western flank of the Eastern Cordillera these rivers are therefore short, and appear as unimportant features on the general map of Australia. The general facts as to relief and drainage may be pictured if we think of the Appalachian Mountains as the only watershed in the United States. From the eastern flank of this divide imagine a group of streams flowing to the Great Lakes, another group to the Gulf of Mexico, and the Ohio in between flowing westward to an evaporating basin in Oklahoma. Think of all the rest of the country between Canada and Mexico as a dry, monotonous plain, devoid of rivers, extending almost to the Pacific Coast, say as far as the Sierra Nevada and the Cascades. The hills known as the MacDonnell ranges do, it is true, rise above the general level, but they only serve to accentuate the general appalling flatness of the continent. Where the transcontinental railway traverses this plain there is one portion of the track with negligible grades which is as straight as a stretched string for 330 miles without a bridge.

The explanation of these remarkable features of Australian physiography is of course to be found in the geological history of the continent. The greater



THE NULLARBOR PLAIN

THE TREELESS WASTE THROUGH WHICH THE TRANSCONTINENTAL RAILWAY RUNS FOR HUNDREDS OF MILES WITHOUT A CURVE OR A BRIDGE. THE PLAIN IS UNDERLAIN BY LIMESTONE CONTAINING MANY SINK HOLES AND UNDERGROUND CHANNELS INTO WHICH THE SCANT RAINS PROMPTLY FLOW, SO THAT THERE ARE NO WATER COURSES ON THE SURFACE

GLACIATED PAVEMENT DUE TO PERMIAN GLACIATION

HALLETT'S COVE, NEAR ADELAIDE. THE GRADUAL STRIPPING OF THE TILLITE BY THE WEATHER HAS EXPOSED AS FINE A *roche moutonnée* SURFACE, POLISHED AND STRIATED, AS COULD BE FOUND IN THE GLACIATED REGIONS OF CANADA OR THE HIGH SIERRA

part of the surface appears to have been reduced in Precambrian time to a peneplain which has persisted in the geomorphy ever since. In Cambrian time geosynclinal basins of sedimentation were developed on the southern and northwestern margins of this peneplain, as its limits are known to-day. In the southern basin the normal process of marine sedimentation was interrupted by a continental glaciation, the ice flowing toward the equator from a land mass now vanished which was located in the region of the Great Australian Bight. On its retreat this ice sheet left extensive moraines, about one thousand feet thick, which are now exposed in the Mount Lofty Range near Adelaide as tillite. Marine sedimentation was then resumed and the tillite was deeply buried in the geosyncline by the later Cambrian deposits, the total thickness of the Cambrian being about ten thousand feet. The southern basin has suffered acute deformation, but the date of this diastrophism is uncertain. The Cambrian basin on the northwest side of the continent has been much less deformed. The sedimentary beds are several thousand feet thick and rest on lavas which are probably also of Cambrian age.

On the eastern side of the early continent, in the region of the present Eastern Cordillera, there existed a persistent, or recurrent, geosyncline throughout Paleozoic time, certainly from the end of the Cambrian on, and possibly also including the Cambrian. In this trough there accumulated vast thicknesses of Ordovician, Silurian, Devonian, Carboniferous and Permian strata. The formations in this trough suffered deformation by folding, locally at the end of the Ordovician, generally at the end of the Silurian and generally at the end of the Carboniferous. These diastrophic movements gave the Eastern Cordillera their mountain structure, but the high ranges, which were also an expression of these movements, were worn down to

low relief before the advent of Permian time; since there are widespread Permian formations over the region which exhibit little or no folding. The maxima for the thicknesses of the several divisions of the Paleozoic in eastern Australia as given by David, are: Ordovician, 9,000 feet; Silurian, 4,000 feet; Devonian, 33,000 feet (including volcanics); Carboniferous, 20,000 feet, and Permian, 15,000 feet (including volcanics). The source of these vast volumes of sediment is an interesting question. It appears improbable that they came from the west, since the western part of the continent was a stable region of low relief, incapable of supplying sediments in large quantities. This makes it probable that the Paleozoic sediments were derived from a land mass which lay to the east of the present eastern coast of Australia. The core of the Fiji Islands, New Caledonia and perhaps New Zealand may be remnants of this almost vanished continental area. On this supposition of an eastern derivation of the Paleozoic sediments of Victoria, New South Wales and Queensland, the Eastern Cordillera becomes analogous to the Appalachian mountains, the Paleozoic sediments of which were derived from the land mass called Appalachia, now almost vanished beneath the waters of the Atlantic. And the analogy persists in the relation of the antecedent geosyncline to the Australian continent, and in the collapse of that trough toward the end of the Paleozoic, when it became overladen with sediments. Still another point of analogy is the fact that the Eastern Cordillera is in no sense the ranges which were formed at the time of the collapse, but are due to a more recent uplift of the region after those ranges had been reduced by erosion to low relief, just as the Appalachians are due to the post-Cretaceous uplift of the peneplain to which the ranges, formed at the time of the Appalachian Revolution, had been reduced.

The Permian Period which followed after an interval of partial peneplanation was inaugurated by outpourings of volcanic lavas and by glacial conditions. A vast continental ice sheet overrode the greater part of the continent, perhaps more than once, advancing from the region of the present Great Australian Bight, which must then have been a land area. On its retreat, or retreats, this ice left morainic sheets which now appear as tillite at many widely spaced localities in the basal division of the Permian. And these tillites may be seen to rest upon scored and polished *roches moutonnées* pavements as perfect as any due to the Pleistocene glaciation of North America, or to the Alpine glaciation of the Sierra Nevada. This widespread glaciation of Australia was contemporaneous with a similar glaciation of South Africa, South America and India and was a manifestation of glacial climate far more extensive than that of the Pleistocene. It is remarkable that, though the evidence of this Permian glaciation is abundant in the several continents, it is all found in regions much closer to the equator than to the poles. The relatively small extent of the land areas in the southern hemisphere may explain this fact south of the equator; but in the northern hemisphere Permian rocks are widely distributed and are well known, yet the evidence of Permian glaciation is scant and such as has been found is nearer the equator than the North Pole. Immediately after this glacial epoch conditions prevailed which were favorable to the accumulation of coal, and the principal coal measures of Australia are in the upper division of the Permian.

In early Mesozoic time certain parts of the present Eastern Cordillera were the site of the accumulation of freshwater beds, chiefly fluviatile, as shown by the common crossbedding of the sandstones, but in part lacustral, as indicated by shales, and comprising occa-

PERMIAN TILLITE RESTING ON GLACIATED PAVEMENT OF CAMBRIAN QUARTZITE
HALLETT'S COVE, NEAR ADELAIDE

sional coal seams due to local swamp conditions. These Triassic formations, to a maximum thickness of about three thousand feet, succeed the Permian without discordance, and as in many other parts of the world are significant of the persistence of the continental conditions of the Permian into the early Mesozoic. These formations considered as a whole represent the building up of a great delta, or series of deltas, by rivers commonly and characteristically laden with coarse sand, which doubtless was the product of the erosion of the high parts of the primitive Cordillera. The subaqueous portion of the delta is unknown. It either extends below the later Mesozoic rocks of the Great Artesian Basin or is now beneath the Pacific and, therefore, was deposited beneath the Pacific. If the second of these alternatives be correct then the eastward extension of the continent, from which the Paleozoic sediments were derived, had, in large measure at least, been engulfed not later than the beginning of the Mesozoic.

With the progress of Mesozoic time, the area of depression, and therefore of sedimentation, shifted westward, and an extensive formation of fresh-water beds accumulated in the region of the present Great Artesian Basin. These are chiefly sandstones with occasional coal seams, and doubtless also represent the flood-plain deltaic deposits in a subsiding basin. The rise of the flood-plain by deposition was sufficiently rapid to keep it above sea-level throughout Jurassic time, notwithstanding the sinking of the floor of the basin. The thickness of the beds ranges from a few hundred feet to three thousand feet, and the maximum figure is the probable measure of the amount of depression.

In Cretaceous time, whether by an acceleration of the rate of sinking, or by a decrease in the sedimentary upbuilding of the flood plain, or by a rise of the surface of the ocean, the salt water invaded the basin and a broad epicontinental sea was formed, the transgression coming from the north in the region of

the present Gulf of Carpentaria. At the same time there was a similar transgression of the south coast from the Great Australian Bight. At the maximum of this Cretaceous inundation the southern sea was probably confluent with the northern, so that Australia was divided into two islands. The strata laid down in the northern basin have not yet, however, been traced in actual continuity with those deposited in the southern basin, and there may have been a narrow isthmus connecting the two insular masses.

This epicontinental sea, having an area of nearly half of Australia, filled up with Cretaceous sediments to a maximum thickness of two thousand feet, and when the basin was full the streams from the surrounding country added still other deposits of fresh-water sand to a thickness of a few hundred feet. The withdrawal of the marine waters left a low-lying arid plain which persists to this day, but slightly modified by the dissection and partial removal of the upper fresh-water sands. The partial submergence of the Australian continent by the Cretaceous sea was synchronous with a similar transgression of that sea over the greater part of North America and Europe, as well as a notable rise of the strand all around the continent of Africa. Such a widespread transgression of all the lands of the earth can only be explained as due to: (1) a universal depression of land surfaces relatively to sea-level, or, (2) a universal rise of the sea-level, or (3) a combination of depression of continents with rise of sea-level. The universality of the Cretaceous transgression implies the operation of a general cause; and whichever one of the three explanations may be considered the more probable, the fundamental cause is still a geological mystery.

The absence of formations which can be referred positively to the Eocene is an interesting feature of the geology of Australia. After the filling of the Cretaceous epicontinental sea with sediment the surface of the continent was slightly elevated so as to exclude the sea of Eocene time, and some of the Cretaceous beds were removed by erosion; but in later Tertiary time it was again rela-

PERMIAN TILLITE, AT SEAHAM, N. S. W.

CONTORTED VARVED SHALES OF PERMIAN TILLITE, AT SEAHAM, N. S. W.

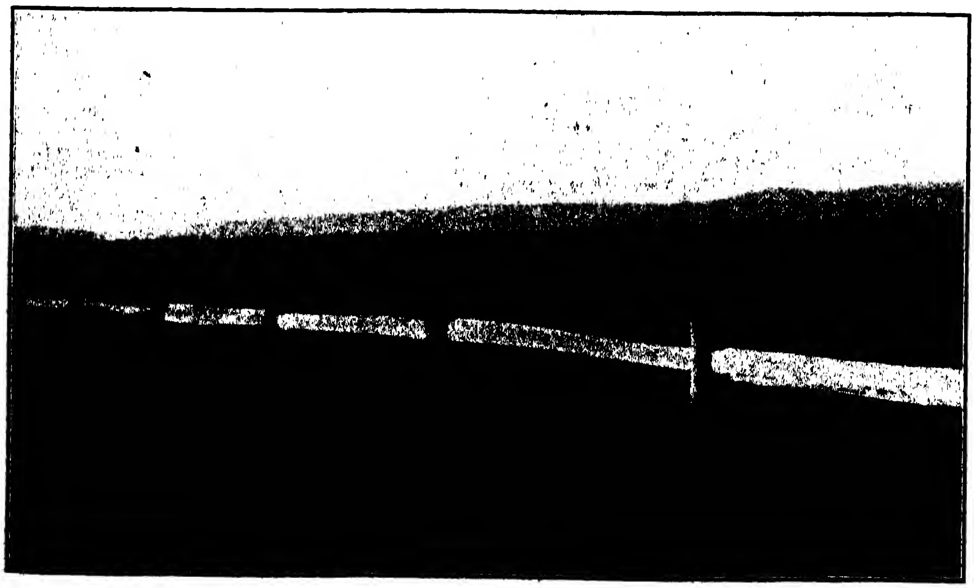
THE DEFORMATION OF THE BEDS IS DUE TO THE PUSH OF THE GLACIER WHEN THE DEPOSITS WERE STILL PLASTIC

tively depressed so as to permit of a marine transgression, particularly from the south. Marine beds of Miocene age rest on the Cretaceous in a large lunate area north of the Great Bight, and these attain locally a thickness of one thousand feet. In the south central part of the continent, the dry plains crossed by the transcontinental railway represent the uplifted Tertiary sea-floor, which has been preserved in an almost wholly undissected condition owing to the absence of running water. The scant rains sink immediately into the porous rocks of the terrain and drain to the Southern sea by underground flow. There are no water courses at the surface for hundreds of miles.

In the region of rifts and graben near Adelaide marine Pliocene beds were deposited in local basins to a maximum thickness of about one thousand feet, as shown by borings. On the whole the area which was submerged in Tertiary time and received thereby a deposit of marine sediments was very limited. But this defect in Tertiary sedimentary strata was compensated for by the general activity of volcanoes. At various times throughout the Tertiary there were extensive extrusions of lava in the eastern and southeastern part of the continent. In this period also Tasmania became separated from the mainland by a slight submergence of the preexistent isthmus. At the end of the Tertiary an elevatory movement was inaugurated along the eastern margin of the continent, and the uplift, continuing down to the present, has given rise to the warped plateau, which in its present state of dissection is known as the Eastern Cordillera.

Although Australia was heavily and extensively glaciated in the Cambrian and Permian glacial periods, it was scarcely affected by the glaciation of the Pleistocene except for the highlands of Tasmania. The Alpine glaciers of Mount Kosciusko have left their record

of refrigeration, but there was no continental ice-sheet anywhere in Australia. This fact serves to bring out the relative intensity of the early glaciations compared with that of the Pleistocene in the Southern Hemisphere, and the contrast is independent of the factor of altitude, since there is no evidence that the Australian continent was notably higher within its present confines in Cambrian and Permian times than it is to-day. But while Australia was not glaciated in Pleistocene time it was affected indirectly by the development of continental ice-sheets in other parts of the world. These ice-sheets were so extensive and so thick that the abstraction of water from the ocean to form them lowered the surface of the sea and permitted the streams to cut valleys in the continental margins to lower levels than before or after glaciation. When the water was restored to the sea by the melting of the great ice-sheets the surface of the sea rose and invaded the valleys. Drowned valleys in the shape of splendid harbors are thus characteristic of the coast of Australia, particularly its east and southeast coast. But from the end of the Tertiary down to the present there has been in progress a slow elevatory movement of the eastern margin of the continent. The drowned valleys show that the rate of this uplift has been slower than the rate of down cutting of the valleys. But however slow it may have been, it is apparent that the strand of the sea, as restored by the melting of the last glaciers, would not reach so high on the coastal slope as did the earlier strand before the sea surface was lowered. That earlier strand would, therefore, be expected as a geomorphic feature of the coast above the present functional strand. Such elevated strands are a common feature of the east coast of Australia at about fifteen feet above sea-level, and their altitude may be taken as a measure of the amount of uplift to which the coast has been subjected in the



BROADSIDE VIEW OF THE DARLING FAULT SCARP

ON WHICH THE WESTERN MARGIN OF AUSTRALIA, NEAR PERTH, HAS BEEN DROPPED ABOUT 1,000 FEET. ON THE SURFACE OF THE DROPPED BLOCK DELTAIC ALLUVIATION HAS BUILT UP THE COASTAL PLAIN SEEN IN THE FOREGROUND

interval of the last lowering of the sea surface.

It has been suggested that, just as the Paleozoic sediments of the Appalachian trough were derived from the waste of the land mass of Appalachia, which has since for the most part sunk beneath the Atlantic, so the Paleozoic sediments of the East Australian trough were derived from a land mass to the east of the present continent, which has since almost entirely sunk below the Pacific. The Permian glaciation suggests the former existence of a large land mass in the Great Australian Bight. This fragmentation of the primitive Australian continent and the shrinkage of its area by the foundering of its periphery are further indicated by movements of later date. The Darljng fault scarp of Western Australia, a post-Tertiary feature, is clearly due to the dropping away from the continental plateau of a coastal block, upon the depressed surface of which has been built up the present coastal plain by the extension of stream deltas and the counter extension of dunes from the shore. The Sterling Range fault, in the southwest corner of Western Australia, is an expression of the dislocation of that corner from the main plateau, with downthrow seaward to the southwest. The abrupt change of level, between the southern margin of the continental shelf and the sea-floor of the Great Bight, suggests a similar dropped block with no coastal plain, the fault lying far to seaward of the sea-cliffs. Since the southern margin of the continent is here veneered by marine Miocene beds the dislocation and dropping of the block must be post-Miocene. The rifting in the vicinity of Adelaide, which resulted in Spencer Gulf, Vincent Gulf and Torrens Lake, is a manifestation of continental fragmentation, part of which at least is post-Tertiary. The coastal region about Melbourne has been dropped relatively to the interior plateau in post-Tertiary time by the Bacchus Marsh fault. The post-Miocene separation of Tasmania by the depression of Bass strait appears to be another step in the fragmentation process. On the east side of the continent the post-Tertiary uplift of the plateau, which by dissection gave rise to the Eastern Cordillera, was accompanied by a relative depression of the coast. At the front of the Blue Mountains of New South Wales this was effected by a monoclinal fold. Farther south to the west of Lake George the same displacement found expression in a fault indicated by the Cullarin scarp. In Queensland great normal faults with downthrow seaward are prominent features of the geological structure of the coast for over two thousand miles. The Great Barrier Reef is regarded by Australian geologists as sessile upon a dropped block.

It is thus evident that the Australian continent on the west, south and east presents a foundering coast to the ocean. As there is reason to believe that the southern extension of the continent from which the Permian glaciers moved north over more than half of the continent has been engulfed, and that the land mass to the east, whence were derived the Paleozoic sediments, has been similarly engulfed, so we may see in the physiography and structure of the coastal region good reason to believe that the process of foundering and engulfment is still going on. It is thus fairly certain that Australia is to-day but a remnant of its former extent, and that with the persistence of the process of fragmentation it will in the future become still smaller. What engulfment of the fragments means is a geological mystery, but there is many a fact that stares us in the face of which the same may be said. It is safe to say, however, that the fragmentation of the continental margin is a process of adjustment to gravitative stresses due to progressive crustal instability. But this is merely

a restatement of the problem. The mystery remains.

The distribution of population and the nature of its industry in the continent thus geologically characterized are determined largely by its climate. The two chief factors in the climatic control of man's migrations and activities are the humidity and temperature of the air. A brief reference will therefore be made to these, as they vary over the surface of Australia.

The south central part of the continent, the area of which is not well determined but is between one quarter and one third of the whole surface, has a rainfall of less than ten inches. This arid country extends as a belt widening eastward from the shores of the Indian Ocean nearly to the longitude of Melbourne, and from the tropics to the shores of the Great Australian Bight. Concentric with the boundary of this central arid region is a belt, broad on the north and east but narrowing to nothing on the south, having a rainfall of between ten and twenty inches. This belt comprises about one third of the area of the continent. Outside of this is a much narrower belt, with a rainfall of twenty to thirty inches. The remainder of the continent, a little more than one tenth of its total area, adjacent to the coast, has a rainfall of over thirty inches.

The seasonal distribution of rains is important in its influence on agriculture. In the summer months from November to April inclusive, the rains come in the north and the south is dry; while in the winter the south receives its rain and the north is dry. But in the coastal regions of Eastern Australia the rain is fairly evenly distributed throughout the year. The rain which falls in the wheat-growing season, April to October, is particularly valuable. Half a million square miles of Australia receive a rainfall of ten inches or more during these months, and this is the limit of the wheat-growing area. If we assume that one quarter of this area, about 125,000 square miles, has a soil suitable for wheat, then at ten bushels per acre Australia could produce eight hundred million bushels of wheat. But fallowing and rotation of crops would reduce this to four million bushels annually. And the average yield would be still farther reduced by occasional crop failure due to drought. The recognition of the fact that wheat may be grown in regions of very scant rains if those rains come in the growing season has led to a great extension of this branch of agriculture in recent years, particularly in South Australia and Western Australia. The present production of wheat in Australia is about one hundred million bushels.

A rainfall of ten inches or more, without regard to the season of its fall, has generally been held to determine the area suitable for the pasturing of sheep. Thus in those regions where the rains fall from April to October the pastoral industry now meets the competition of agriculture for the utilization of the land. The shepherd generally yields to the farmer and is turning more and more to the interior desert for pasture for his increasing flocks. This larger utilization of the desert for pasturage has been made possible in recent years by the extensive development of artesian water in regions where there is no water at the surface, although there may be adequate vegetation to sustain flocks of sheep.

Two thirds of the area of Australia is in the south temperate zone and one third is in the tropics. For the two hottest months of January and February the mean temperature in the tropics is from eighty to eighty-five degrees, while in the temperate zone it is from sixty-five to seventy degrees. For the coldest month, July, the mean temperature in the tropics is less than seventy-five degrees, and in the temperate zone less

than fifty degrees. The summer heat in the temperate zone is dry, and, owing to the clear skies which prevail, radiation is active, so that the nights are agreeably cool. In the tropics the prevailing temperature is favorable to sugar-cane, cotton and rubber in regions where the rainfall is ample. Of these the cultivation of sugar-cane is an established industry, particularly in Queensland, where there are many sugar mills. On the plateau lands of the tropics, away from the coast, where the rainfall exceeds twenty inches, cattle do well and there are many herds; but the business of exporting beef is at present suffering from the competition of the Argentine.

These general physiographic and climatic features of Australia have determined the permanent concentration of its population in the more humid and cooler coastal regions, while the great interior of the continent remains an uninhabited desolate wilderness. As an illustration of how real a barrier the desert is to migration it may be of interest to note that while the English sparrow flourishes in Eastern Australia, it has never been able to make its way across central Australia to the west coast. A few years ago two sparrows were brought in a cage on a French ship to Fremantle, where they escaped. When this fact became known the entire population of Western Australia was seized with a panic; all the guns in the country were requisitioned and a great hunt was organized. It was only when the two poor sparrows were eventually shot dead and their carcasses properly identified by ornithological experts, that the people with a great journalistic sigh of relief resumed their normal occupations. After many years the rabbit succeeded in getting across the desert, and rabbit-tight fences were promptly built across the western side of the continent to hold him to the desert.

Man has been scarcely more successful than the sparrow, and the well-watered fertile soils of the west coast have been peopled not by overland migrations, as in the case of our middle west, but by ships as in the days when our goldseekers went around the Horn.

Like California Australia had its gold rush in the middle of the nineteenth century, and the temporary concentration of population thus occasioned was on the climatically agreeable eastern and southeastern side of the continent. The gold placers were found in regions where the older metamorphic and granitic rocks form the terrane; and they were reached from harbors where Brisbane, New Castle, Sydney, Melbourne and Adelaide have since established themselves as great metropolitan and industrial centers. The exploitation of the placers led to prospecting for the sources of the gold which enriched them, and so gold-bearing quartz reefs were discovered and mining camps were founded on both sides of the continent, which have become famous for their output of bullion. These were all located in the same terranes of ancient metamorphic and granitic rocks, and were all tributary to the growing cities of the coast, including Perth on the west. The successful exploitation of the gold mines led to the discovery of ore bodies in which copper, lead, zinc, silver, tin and iron were the chief metals, and these were extensively worked as gold-mining gradually declined. The discovery of telluride gold ores at Coolgardie and Kalgoorlie on the western margin of the great interior desert and the remarkable output of the older Mt. Morgan mine in Queensland led to a great revival of interest in gold-mining at the beginning of the present century. These great mines have been prolific of gold for several decades, but are now approaching exhaustion of profitable ore. The mines at Kalgoorlie have built a substantial city in the desert, but only at the expense of a thirty-inch steel pipe through which the water is lifted from the coast

and pumped by relay stations for 350 miles into the dry interior. When the mines are eventually exhausted and abandoned, the major use for the water will be on the fertile soils farther west, and the hitherto flourishing city of Kalgoorlie will become not less desolate than the buried cities of the deserts of Turkestan. But even if the mining of gold were now to wholly cease in Australia, the stoppage would not endanger the prosperity of the country. In the seventy or eighty years during which gold-mining has flourished it has not only served as a stimulus to the influx of a population possessed of great vigor, and has exercised a notable control in the distribution of that population, but it has contributed in large measure to the building up of the great cities of the coast, and has supplied and happily distributed the capital necessary for the establishment of more permanent pastoral and agricultural industries.

Australia is fortunate in having in the region of dense population a most agreeable climate, fine harbors and vast quantities of excellent coal. The best coal is found in various horizons of the Permian near the eastern coast, but coal of less importance is also found in Mesozoic and Tertiary formations. This coal and the existence of iron within convenient reach has led to the establishment of a great steel plant at New Castle, about one hundred miles north of Sydney, on the coast. No oil has yet been found in the rocks of Australia, but the day is rapidly approaching when it will be found profitable to extract from coal all the gasoline needed for her automobiles and other gas engines, and the failure to find oil will cease to be a cause of chagrin.

The most notable industry of Australia and her most important source of wealth is the growing of wool. The total number of sheep in Australia at the present time is reported to be about 106 million, or about twenty-four for every head of population. The flocks are limited in their distribution to regions where the annual rainfall is in excess of ten inches. Where that rainfall occurs in the winter months there is a steady tendency to use the land for wheat-growing and so restrict the pastoral area. But this is more than compensated by the gradual extension of the pastoral area in the dry interior of the continent, particularly where water is obtainable from artesian sources. The development of underground supplies of water in the dry eastern central part of the continent is a notable feature of the economic progress of the country. Here a great basin of undisturbed Mesozoic rocks extends from the Gulf of Carpentaria across Queensland into northern New South Wales and South Australia, occupying more than one quarter of the area of the continent. This basin receives the drainage of the western flank of the Eastern Cordillera of Queensland, and the lower formations of the basin are saturated with water which promptly rises to the surface when these formations are pierced by borings. The utilization of this supply has made possible the establishment of sheep stations with vast flocks in regions where there is no surface water, although there is sufficient vegetation to support sheep. The supply is very large and borings are being steadily extended, but it is of course limited by the replenishment from the drainage of the Eastern Cordillera. When the annual draft on the underground supply equals the annual replenishment the limit will have been reached. So far as I am aware little or none of this artesian water is used for irrigation in agriculture, doubtless due to the remoteness of markets and the lack of transportation facilities.

The steady growth of the pastoral industry from the beginning of the nineteenth century to the present and the remarkable improvement in the breeds of sheep and the quality of wool indicate

that the altitude, climate and vegetation of Australia are especially favorable to the life of the animal which has contributed so much to the prosperity of the country. There is every reason to believe that the production of high-grade wool will steadily increase for an indefinite time; and this permanence and stability of the pastoral industry of course implies a very thinly populated land, with few settlements that could be called villages, very meager transportation facilities and very few roads such as are common in a farming country. The interior region where sheep flourish is and will always remain a wilderness; and, although farmers in the agricultural districts nearer the coast have their flocks, the great bulk of the wool comes from the stations in the wilderness. These stations in the interior are immense holdings running into hundreds of thousands and even millions of acres for individual concerns, which are leased on a very small rental but which are subject to ultimate subdivision and sale if the land proves available for agriculture. When we add to the dry sheep country the vast territory which is so arid that it never can support flocks or herds the immensity of the wilderness relatively to the populated areas becomes most impressive.

Besides the production of wool the pastoral industry is the basis of a large export trade in mutton, beef and hides, which, however, owing to competition, is not at present so profitable as the wool trade.

In recent years Australia has made notable advances in horticulture and produces now not only an abundance of fruit for domestic consumption, but also some for export. The apples of Tasmania particularly are shipped in increasing quantities to Europe. The hardwoods of Western Australia have also become an article of commerce.

The principal exports of Australia arising from its productive industry are thus: wool, mutton, beef, hides, wheat, oils, specie, metals, fruit and hardwood. The principal imports are: clothing, manufactured metals, foods, Oregon pine, paper, drugs, alcoholic drinks, oils, leather, jewelry, earthenware and tobacco. In its past history Australia has imported most of the necessities and luxuries of civilized life and has met these imports by the export of a few staple commodities in world-wide demand. To-day there is a pronounced tendency toward becoming more self-sufficient. Manufactures in great variety are being developed in the centers of dense population. The new steel plant at New Castle has been mentioned. This will greatly minimize the imports of rails and structural steel and will supply steel for many manufactured articles that were formerly imported. The sugar mills of Queensland now supply sugar for the whole of the commonwealth. New woolen mills are meeting a part of the demand for woolen fabrics. Quarries, ceramic plants and cement mills are supplying the bulk of the building materials used. The native woods are coming into more general use. Machine shops, foundries and engineering works are common in the cities. The manufacture of vehicles, harness and saddlery dates from early days, but is now feeling the advent of the automobile. Of printing, engraving and the making of books there is no end. Furniture, bedding, upholstery, chemicals and drugs are produced in increasing quantities. The day is approaching when Australia will be relatively as self-sufficient from an economic point of view as the United States or Canada. Yet its deserts will always be inhospitable. Its physiography and climate determine that it will always be essentially a pastoral and agricultural country, that it will always export wool and wheat. As its manufacturing self-sufficiency in-

creases its imports will more and more take the form of luxuries rather than the necessities of life.

The insular character of Australia, the concentration of its people near the coast and their dependence on the sea for touch with the rest of the world, have determined that it shall be a maritime nation. Their travel has always been by sea and all their commerce has been sea-borne. Surrounded by the sea the Australians have a sense of unity and unchangeable completeness of domain which is not found in Europe or America. To them the sea is a kindly element which is part of their possessions. Throughout the nineteenth century before the confederation of the separate colonies into the commonwealth there was a well-established coastwise trade between the various coastal cities, besides the overseas commerce. The facility which the sea afforded for travel and for commerce between these now great cities has had an interesting influence on railway construction. When railways were first built in the middle of the nineteenth century little attention was paid to through traffic. The various colonies built their railways with little regard to what their neighbors were doing. The purpose of railway construction was to facilitate travel and the hauling of freight within the boundaries of each colony. Intercolonial travel and commerce by rail was not considered important because the ships took care of that, though it would be interesting to know what hand the shipping interests had in the matter. The indifference to through or intercolonial traffic is clearly shown by the fact that each colony determined upon, and maintains to this day, a railway gauge of its own. The gauge in Queensland is 3′ 6″, in New South Wales it is 4′ 8½″, in Victoria it is 5′ 3″ and in South Australia and Western Australia it is again 3′ 6″. The new transcontinental railway built by the commonwealth between Port Augusta and Kalgoorlie is the standard gauge 4′ 8½″. The latter was built for political reasons as a condition of Western Australia's coming into the Confederation. It has been running now for several years, but there is no economic or business reason for its existence. Nobody lives in south central Australia on the line of the railway except the people who run the railway. There is a small amount of transcontinental passenger traffic, most of it as part of the travel between England and the cities of eastern Australia; but there is no freight to carry. All freight goes by sea. Imagine a railway system in America trying to maintain itself without freight! And yet another transcontinental railway is now in process of construction from Port Augusta to Darwin, although there is no more hope of freight for the new line than for the existing one. As long as the people of Australia live along the coast so long will freight be shipped by sea from one part of the coast to another; and no railway dependent upon freight for its economic justification has a hope of survival.

THE NEBULAR HYPOTHESIS IN THE NINETEENTH CENTURY

By Professor CHARLES CLAYTON WYLIE

THE UNIVERSITY OF IOWA

THERE is little doubt that the nebular hypothesis of Laplace exerted an important influence on the scientific thought of the nineteenth century, but the extent to which it was completely accepted by scientific men is often overstated. In a recent popular article by an eastern psychologist it is referred to as:

that first theory of modern evolution propounded about 1800 by Pierre Simon La Place and called the nebular hypothesis, which is taught in all our high schools and colleges and accepted without murmur or dissent by many of our most devoted church members. It affirms that every physical object in the universe got here by the original motion of particles of matter, or star dust, infinitely small, scattered throughout space. By Newton's laws of motion the particles attracted each other, rushed together in space, formed rotating masses like our sun, which cooled and threw off smaller masses making planets, which in turn cooled, hardened, and formed among others our earth. . . . It showed how, without the intervention of mind, our material world is controlled and how it came into being.

In an article on paleontology by an eastern professor the following appears:

For over a hundred years, the Nebular Hypothesis of the great French astronomer, La Place, was accepted by astronomers and geologists with practical unanimity, as explaining the origin and history of the solar system. Now that hypothesis has no standing with astronomers and among the geologists of England and America, the ancient hypothesis is completely abandoned, for it has been conclusively shown that La Place's conceptions are mechanically impossible.

In a modern very excellent text on astronomy the following statement concerning the nebular hypothesis is made:

This theory for many years was generally accepted as giving a reasonable explanation of the mechanical development of our solar system, and, with certain modifications, is still accepted by some scientists.

Recently, a professor of astronomy in discussing the modern theories of the origin of the solar system with a group of scientific men remarked:

Astronomers will never become as enthusiastic over another theory as they once were over the nebular hypothesis. They have learned a lesson.

Some of the statements quoted are distinctly in error, while others are merely slightly misleading. The name is "Laplace," not "La Place." It is certainly not taught in all our high schools and colleges. The devoted church members who accept the hypothesis without murmur or dissent are following neither Laplace himself nor modern astronomers. Laplace did not outline a plan for the development of the universe, but for only a part of the history of the solar system. It should never have been considered as "explaining" the solar system, since it was merely the guess of an eminent astronomer as to the general outline of the explanation. In sketching the standing of the nebular hypothesis in the nineteenth century, one might well start with Laplace himself.

The nebular hypothesis was presented as the concluding pages of a book of popular character, "Système du Monde." In this book he remarks "—for first causes, and the ultimate nature of things, will be forever unknown to us." He presents the hy-

pothesis "with the distrust which anything not a result of observation or of calculation ought to inspire"; and gives only a bare outline. He more than once passes from one step to the next with "One can guess," and near the end inserts, "if the conjectures which I venture to propose on the origin of the planetary system are correct." For the benefit of those not familiar with this famous speculation, it may be worth while to state that Laplace assumes the sun in rotation and surrounded by a fiery nebulous atmosphere, which extended beyond the outmost planet. He assumed that, as it condensed, the accelerated rotation caused rings to be left behind, which eventually collected into the planets; and, "One can guess furthermore that the satellites have been formed in a like manner by the atmosphere of the planets." We, in our turn, may guess that Laplace considered it an interesting speculation and worth while, but he wanted his readers to understand that the guesses, even of an expert, are in a very different class from the scientifically demonstrated facts presented elsewhere in his book.

Two of the world's leading astronomers in the period immediately following Laplace were Arago, in France, and Herschel, in England. Both wrote popular books on astronomy, Arago's four-volume work, "Astronomie Populaire," appearing after his death, which occurred in 1853, and Herschel's "Outlines of Astronomy," appearing about 1836. In Arago's work the hypotheses of Laplace are referred to, but not given. The earlier hypothesis of Buffon is outlined and discussed at length. In the tenth edition (1858) of Herschel's work, the "nebular hypothesis" is mentioned and a few speculations given, none distinctly from Laplace, nor is his name mentioned. Following the reference Herschel writes, "But to return from the regions of speculation to the description of facts." In Grant's history of astronomy, published in England in 1852, nearly a column is printed in the index under the heading "Laplace," but the nebular hypothesis does not appear, nor was any reference to it noticed in casually looking over the pages of material on that famous astronomer. Evidently the astronomers of this period were not greatly interested in the speculation.

Darwin's famous book appeared in 1859, and in works on astronomy appearing immediately after its publication we find evidence that the hypothesis of Laplace was being thoughtfully considered. Professor Loomis, of Yale, wrote in 1865: "The nebular hypothesis must therefore be regarded as possessing considerable probability, since it accounts for a large number of circumstances which had hitherto remained unexplained." In this period, when men of reputation were giving it almost unqualified endorsement, the details of the hypothesis were examined, and difficulties were brought to light which did not appear in the bare outline sketched by Laplace. In 1861 it was announced that there were serious difficulties in getting the periods of the hypothetical Laplacian rings to agree with the periods of the planets. Kirkwood, in 1867, thought the evidence gave "the theory of Laplace a very high degree of probability," but about two years later published a difficulty which he had discovered. Others were finding difficulties, but in 1877 Simon Newcomb wrote in his "Popular Astronomy," "These difficulties may not be insurmountable."

A somewhat more critical opinion is expressed in the well-known "History of Astronomy During the Nineteenth Century" by Clerke (published 1885, revised

1887). This opinion, ten years after Newcomb's, is: "It is, nevertheless, admittedly inadequate. Of much that exists it gives no account, or an erroneous one. It is certain that the march of events did not everywhere—it is doubtful whether it did anywhere—follow the exact path prescribed for it. Yet modern science attempts to supplement, but scarcely ventures to supersede it." Several of the more serious difficulties are discussed briefly. In Ball's "Story of the Heavens," a book of popular character published about the same time as Clerke's history, a modified version of the hypothesis is given, incorporating points from other writers than Laplace. In fact Laplace's name is not mentioned. Ball does not mention specific difficulties, but at the start warns his readers that "It is merely a conjecture," and after outlining his version adds, "Such a speculation may captivate the imagination, but it must be carefully distinguished from the truths of astronomy, properly so called." From these and other writings of the period, it seems that forty years ago those who had investigated the question at all were fully aware that the story as developed in the nebular hypothesis was quite unsatisfactory. A few interested persons had suggested modifications; but the theory involved too much speculation and imagination to receive much serious attention in scientific circles. Because it was the sort of thing to "captivate the imagination," it was presented in many popular books and elementary texts almost as a well-established truth.

The first serious work on the theory which has supplanted the nebular hypothesis was commenced by the geologist, Chamberlin, and the astronomer, Moulton, at the University of Chicago nearly thirty years ago. Instead of starting with a nebula or a star surrounded by a nebulous atmosphere, as in the earlier theories, they assume the sun existing in a state little different from its present condition. It is suggested that the material of which the planets are now composed was ejected by tidal and eruptive forces, when another star passed quite close to the sun. The authors have supported the hypothesis with considerable mathematical work, and Jeans and Jeffreys have also worked on the subject, suggesting modification of several details in the work of Chamberlin and Moulton.

As a typical modern opinion on the origin of the planets, we quote from a recent article by Professor Russell in the *Scientific American:*

> The only available explanation of their existence appears to be the one now familiar—that the planets were ejected from the sun during huge eruptions caused by the close approach of a passing star, and set moving laterally in orbits by the attraction of the star as it receded . . . in the chaotic turmoil which must have followed the great outburst, detailed calculations become impossible, and we have to accept it simply as a fact that eight large masses and vast numbers of small ones remained in motion about the sun.

To sum up: the conclusions after an examination of popular works by leading astronomers of different periods are—that Laplace himself did not take the hypothesis as seriously as writers on popular science of twenty-five to fifty years ago. The astronomers following Laplace were not greatly interested before the publication of Darwin's book. In fact, the theory is not given in the three books examined which appeared just before that work. Immediately after the appearance of this epoch-making work on evolution, Laplace's hypothesis was quite popular, but as a consequence various persons attempted to fill in details omitted by the author, and difficulties were found. At first, naturally, it was generally believed that,

in spite of various difficulties, the general outline suggested by Laplace might be approximately correct; but in less than thirty years the recognized difficulties were such that a scholarly investigator questioned whether any of the details could be correct. Evolution was, however, a popular subject; the prestige of Laplace was great; and nothing worth while had been suggested to supersede the nebular hypothesis; so popular writers and elementary texts continued to present it until the general acceptance of the more modern theory was recognized.

In conclusion, we may remind readers that speculations on the origin of the solar system, like those about life on other planets, are discussed much more in popular than in scientific circles. Astronomers in general will readily concede the scientific value of Laplace's theory and of the work of Chamberlin and Moulton; but most believe that the average worker should restrict his research rather closely to facts of observation and calculation.

HEREDITARY CONSTITUTION AND X-RAYS

By Dr. ROBERT T. HANCE

DEPARTMENT OF ZOOLOGY, UNIVERSITY OF PITTSBURGH

Is it conceivable that a future Solomon may be able to depend upon a technique for determining parentage that would be more reliable than maternal emotions? It is an interesting thought to play with, although not one for which this article is going to do much by way of prophecy. From the standpoint of the race, the specific parentage of children, beyond the eugenic aspects, is not a particularly important one and, if we are to draw any conclusions from the signs of the times, it is very apt to become less so in the future. Certain criteria are already proving occasionally useful in deciding who the parents of a particular baby may be when the mother becomes suspicious that the youngster delivered to her from the hospital nursery lacks the family "it." The determination of the type of blood (the blood groups) possessed by mother, father and child is satisfactory and entirely conclusive in certain cases but useless in others. The laws of heredity can also be depended upon to produce from blonde parents only blonde offspring, but these same laws will show how two brunette parents may also have blonde offspring. In the former case the birth of a brunette child would be quite adequate proof of a companionate alliance of some sort, while in the latter the legal value of the evidence would be nil, since it might very well be, and probably is, merely a case of so-called Mendelian segregation. Here, though the parents themselves were brunettes they carried the possibility of producing blonde offspring and when the right combination of germ cells occurred the blonde characteristics appeared.

The preceding paragraph perhaps intrigues the reader's interest to a point to which the following exposition of experimental results will prove but an anti-climax. We can not report as yet any conclusions that may apply to the various practical problems which we should so much like solved, but it is entertaining at times to get away from the rigidly defined restriction of scientific procedure and to allow our imaginations full swing. And who knows how hopelessly shortsighted and unimaginative our wildest stretches are going to appear when viewed from the future? Jules Verne in the days of his vogue was considered a delightful romancer. To-day there is little of interest in his stories as all his brain children have been supplanted by eugenic babies that far exceed in fact Verne's strangest imaginary production.

Beginning with the rediscovery of Mendel's work in 1900 a great many studies have been made that have resulted in a rather satisfactory demonstration of the laws that govern the transmission of parental characteristics to succeeding generations. We know, for instance, of the conditions of dominance and recessiveness which involve the appearance or submergence of certain traits. If a mouse whose ancestors are known to be pure bred for colored hair and which is therefore, for this character, itself pure or homozygous, to use the genetic term for this condition, is mated with a pure-bred albino mouse, the offspring will all have colored hair. As is of course very well known to-day, though these first generation hybrids are indistinguishable from the pure

bred colored parent, they produce when bred together black and albino offspring in the ratio of three to one. The first generation hybrids must obviously have carried the albino possibility in a submerged or recessive state. If we use the usual symbols, the hereditary constitution of these animals, as far as the hair color is concerned, will be more obvious. Let us have capital "C" represent the dominant colored-haired mouse and small "c" stand for the recessive albino. Since both animals had two parents, each of which contributed an hereditary determiner for color, the pure-bred colored mouse's formula should be "CC" while the albino will be "cc." In the formation of the germ cells these hereditary determiners separate so that each mature reproductive cell contains but a single determiner for each trait of the body. Considering hair-color alone, each "colored" germ cell would carry a single "C" and each "white" cell a single "c." It may be diagramed as follows:

	Dominant colored	(crossed with)	*Recessive white*
	CC		cc
Germ cells	c		c
First generation		Cc	all colored mice

When two of these first generation animals are crossed, this is the result.

	Cc	(crossed with)	Cc
Germ cells	C c		C c
Second generation— All possible combinations of germ cells	CC	pure or homozygous colored	
	Cc Cc	hybrid or heterozygous colored	
	cc	pure or homozygous white	

From this it can be seen that the recessive character can only appear when it is present in a pure condition or, in other words, when it has been carried by each of the two germ cells that united to form the new animal. On the other hand, it has always been impossible to determine except by breeding tests whether a colored mouse is pure or hybrid for pigmented hair. In the case of a mouse homozygous for colored hair this color has been produced by a double dose of the hereditary determiner for this character, one having come from each parent. The hybrids, however, that are visibly indistinguishable from the others have but one determiner back of their hair color.

Now there has been no evidence that the extra color determiner in the pure bred mice represents or produces anything physiologically different from that found in the hybrid. It has always seemed reasonable, however, that a character supported by two hereditary determiners might be "stronger" than one dependent for its expression on a single determiner. As the result of some recent work we now have evidence of the correctness of this belief.

During these studies on the biological effects of X-rays it was found that, following certain conditions of raying, the pigmented hair of mice is shed and is eventually replaced by hair that is white. The question was raised as to whether there might be any difference in the reaction to X-rays of mice homozygous or heterozygous for hair pigmentation. This was an obviously important point, although at first the possibility of conclusive results with the available methods did not seem great.

The plan of attack involved a general exposure of a number of homozygous and heterozygous colored mice at what had been determined to be a reactive age, from ten to fourteen days. The exposure used was the smallest dose that was known to cause the falling out of hair on the general supposition that if there was a physiological difference between pigmentation that had resulted from either one or two genes a small

dose might serve to change the weaker without affecting the stronger genetic character.

The expectations were entirely realized with certain important and unanticipated additions. The regrown hair on the rayed backs of heterozygous colored mice came in a mixture of pure white and pure colored hairs in ratio of approximately from three to five white to one colored. The general color effect of the mixed hairs was light gray. There was some tendency for the general color effect to become lighter as the animal became older. I am not certain whether this is due to whitened hairs becoming still more white or to colored hairs dropping out.

A few of the hairs on the backs of the homozygous colored mice also came in white, but the majority of the hairs were noticeably darker than normal.

These results have been constant and without a single exception in six litters of homozygous colored mice (fourteen animals) and four litters of heterozygous colored mice (thirteen animals).

The above data seem to prove beyond question that a dominant coat color character that has been produced by a single determiner (in other words is heterozygous) is not as "physiologically strong" as the same color resulting from two determiners (homozygous).

When all is said and done what we are really striving for is more knowledge of the chemistry of living processes in order that we may the better be able to control them. The biologist is trying by every possible means to learn more of these complicated phenomena and it is usually easier to understand the normal through observations of the abnormal. Hence he is continually trying to upset the usual activities by throwing experimental monkey wrenches in the guise of ultra-violet rays, X-rays, chemicals and a variety of other things into the living works to see what happens. The effect of X-rays is attracting most attention at present, and their value in demonstrating a very nice difference (doubtless chemical) between two characters of different hereditary constitution is obvious in the cases just described. This is the first instance where an hereditary difference between two animals has been shown by other than natural breeding methods and it opens a very interesting field for experimentation and speculation.

From the genetic point of view the results of these experiments suggest the possibility of getting at the chemical basis of hereditary and biological phenomena. Any conclusions reached along these lines might very probably have a bearing on the therapeutic aspects of X-radiation. X-ray therapy has some virtues and many faults. Greater knowledge of all phases of the biological action of X-rays may enable us to control or to duplicate in some simpler way the valuable effects and to largely, if not completely, eliminate the less desirable.

But imagination and prophecy aside for the present, we have actually worked out in the described experiment only one thing which may be briefly told as follows. Hair color that is produced by two hereditary determiners has proved more resistant to X-rays than the same character resulting from but one determiner and the only apparent explanation of these reactions is that the former is literally stronger than the latter and consequently required more radiation to kill it. This suggestion gains support from the fact that more severe exposures to X-rays will produce similar results in the homozygous or pure-bred colored mice, while the difference between the pure-bred and hybrid animals appears only when minimum doses are used.

PARASITES OF BLACK BASS

By Professor RALPH V. BANGHAM

COLLEGE OF WOOSTER

AMONG the various factors which limit the growth and reproduction of fish, parasitism plays an important part. There are many causes of the limitation of the numbers of bass in our lakes and streams but only the damage due to parasitism and disease will be considered in this article. It is difficult to estimate the degree of damage due to parasites and disease on adult bass. The host fish is seldom killed. Bass are not often subject to any epidemic type of disease which kills large numbers at one time. Under the unnatural and crowded hatchery conditions certain parasites are sometimes brought in which spread rapidly, causing death of large numbers of bass.

Almost all species of fish carry parasites, and the black bass is no exception. At all ages, from the fry to the adult stage, a bass usually harbors several species of parasites. Young fish are especially susceptible to parasitic attacks. If they do survive their growth is retarded and these fish fall prey to carnivorous fish for a longer period than if their growth proceeded at a normal rate.

Often, in older bass, damage done by parasites is first noticeable in loss of sexual powers. The adult bass are obtained as breeders for the hatcheries from Lake Erie. A large number of these fish are found to be entirely or partially sterile due to the infestation of the gonads with a species of larval tapeworm. Several other states which formerly obtained breeders from Lake Erie have discontinued this practice because of this infestation.

The gills and fins are often attacked with minute flukes which do considerable damage. At times the intestine is so completely filled with masses of tapeworms or round worms that there seems to be but little room for food. As many as fifty larval tapeworms have been taken from the intestine of a young bass less than two inches in length.

Parasitism sometimes occurs in the flesh of the fish, and these so-called "grubby fish" are usually discarded by fishermen, although no harmful effect would result if the fish were eaten.

The parasites of bass belong to several different classes: (1) Plant parasites, fungi and bacteria; (2) one-celled parasites or protozoa; (3) flukes; (4) tapeworms; (5) nematodes or round worms; (6) acanthocephala or thorn-headed worms; (7) fish lice; (8) leeches.

In the first group Saprolegnia or water mold causes damage, especially in the spring. As previously mentioned, many of the adult bass which are used as breeders in the hatcheries are obtained by trap nets from Lake Erie and transported to the hatcheries in tanks by auto trucks. Even with careful handling many are bruised and are attacked by Saprolegnia. There is often serious loss among such fish. This fungus attacks the eggs at certain times, especially those laid by bass of low vitality or eggs laid late in the season.

There are but few bacterial diseases of bass and these are of limited distribution.

The protozoan parasites seldom infest bass under natural conditions. Nearly all these which affect bass are external parasites and are found under hatchery conditions. One of these, the "itch" or "white spot" disease, spreads very rap-

idly and is often the cause of a heavy mortality among young bass. The disease appears as small white pimples about the size of a pin head projecting over the body of the fish. Affected bass are at first very active but soon refuse food, become listless and come to the surface apparently gasping for air.

Another protozoan forms larger white cysts in the gills of the young bass and if sufficiently numerous seriously impairs the respiration of the fish.

One other small one-celled parasite attacks the skin, especially in the region of the fins. A silvery, glossy scum forms over the body and the fish becomes very sluggish. Often portions of the skin fall off before death.

The bass are fairly resistant to certain chemicals, such as weak solutions of alum, copper sulphate, acetic acid, and most of these diseases can be held in check by treatment if the infestation is recognized in time and proper care used in handling the fish. It is much more important in these protozoan infestations as with other parasites to attempt to prevent the disease gaining a foothold than to treat it afterward.

Several species of flukes infest bass. Two species are external parasites, two are found in the skin and flesh and many are internal; these latter being found chiefly in the stomach and intestine.

The internal flukes are probably the least harmful of the bass parasites, but those which are external often do considerable damage to the gills, skin and fins of the host—especially where they are found in ponds where many bass are confined.

Of these flukes one very small species attacks the skin and the fins, causing large raw patches usually near the base of the fins. The losses of young fish in hatchery ponds are often high when this form is present. These parasites are transmitted from one fish to another by contact, and the entire life cycle may be passed on a single fish. Methods of treatment have been developed which are fairly successful in the control of this disease.

A very closely related species of fluke attacks the gills of large-mouth bass. Small numbers of this minute fluke are nearly always found on the gills, but occasionally the numbers are increased so as to cause serious impairment of the respiration. At one Ohio hatchery last year the large-mouth bass breeders became seriously affected. These fish were removed from the pond and treated with a .2 per cent. solution of glacial acetic acid. The treatment was not entirely successful, as the flukes were often deeply embedded between the gill filaments and the solution failed to reach them.

A larval fluke which is the cause of the "grubby bass" is found in the flesh as small round yellow cysts. Often there are hundreds of these larval forms in the flesh of a bass. The liver is also frequently riddled with watery cysts of this species. Two areas where bass were very heavily infested have been found—one in Lost Creek near Troy, Ohio, and the other in streams flowing into Lake Erie from northeastern Ohio. The degree of infestation is higher in late summer. The adult of this parasite is found in the esophagus of certain fish-eating birds. The first larval host is unknown, the bass probably being the host of the second larval stage.

Another smaller larval fluke is often found encysted beneath the skin, causing black pinhead-like spots in the bass of warm lakes and streams. These are seldom found in bass of Lake Erie.

The tapeworms are of the greatest importance as bass parasites. There are six species of these found in Ohio bass, and an individual fish usually harbors

but one or at most two species at a time. Proteocephalus amboplitis, the tapeworm of Lake Erie bass, is the largest and does by far the greatest harm to the host of any of this group. It is the only one of the tapeworms of the bass which has two stages of its life history in the fish. In the larval stage it forms cysts in the liver, mesenteries and reproductive organs. This is the form already referred to as the one causing sterilization of many adult bass. The adult stage is found in the intestine of the bass. The distribution of this form is limited in Ohio to bass of Lake Erie and smaller lakes. It has not been found in stream bass, except near where a lake empties into a stream.

This form has little if any free existence. The egg when it reaches the water must be eaten by the proper species of water flea if it is to develop. When taken by the proper host the larva of the tapeworm burrows through the intestine and continues larval development in the body cavity. If this infested form is eaten by a young bass or certain other species of fish, the host is digested, but the parasite passes through the wall of the intestine and migrates to the liver, spleen and reproductive organs, where a second larval stage is passed. Here the worm leads a more or less inactive life and can not reach maturity unless this young fish is eaten by an older bass. If this occurs the larval tapeworm develops to maturity in the intestine of the bass.

The other species of tapeworms do not seem to cause very grave damage to the host. One form is found in young bass from Lake Erie during their first year. These small tapeworms are obtained by the bass soon after they begin taking food. They are acquired by eating minute water fleas carrying the larval stage of this form. In this form the development proceeds in the intestine of the bass without a second larval stage.

Another form which is intermediate in size between the two above mentioned is Proteocephalus fluviatilis and has been found to infest 90 per cent. of the bass from streams. It is also found only as an adult in the bass. Often from ten to twelve individuals of this species are found in the intestine of a single adult bass.

The nematodes or round worms prove a serious pest to certain species of fish, but very few are found in lake bass. In certain streams of southwestern Ohio a large species of nematode is quite common in bass and may do some damage to the host.

The Acanthocephala or thorn-headed worms live in the intestine of the bass with their long spiny heads embedded in the wall. There are often hundreds in one fish, and the tears made by their hooks may cause severe injury to the host. These are the most common and widely distributed of the bass parasites. Small-mouth bass are usually more heavily infested with these thorn-headed worms than large-mouth bass.

The fish lice are blood-sucking forms usually attached inside the mouth or on the gills. If numerous they cause death of the bass, but only in a few cases are such large numbers found. They are more numerous in warm lakes than on stream bass.

Leeches are the largest of the external parasites and if many of these worms are found they very greatly weaken the host. They very rarely attack the bass in large numbers.

In most cases bass from Lake Erie and smaller lakes showed a higher degree of infestation than those from streams. This finding agrees with that of Essex and Hunter, who reported in 1916 the results of a study of parasites of fish in

the upper Mississippi and Missouri river basin.

The distribution of the parasites in Ohio is especially interesting in light of the fact that adult bass from Lake Erie have been placed by the Fish and Game Division in inland lakes and streams annually since 1883. If the proper intermediate hosts were present the Lake Erie parasites should be widely distributed in Ohio lakes and streams. Yet several parasites are peculiar to Lake Erie bass, such as the small species of tapeworm and several of the internal flukes. The large tapeworm of Lake Erie bass has established itself in certain inland lakes and even in some hatchery ponds, but it has only been found a few times in about one hundred and fifty examinations of stream bass. Where found it was from bass taken near lakes where the lake bass carried this form. It will be hardly possible to control parasitism of fish in natural waters, but it is important to determine the life history of many forms. In many cases it is very difficult to determine with any degree of certainty the harm parasites do to fish. There is need for more light on this problem.

Results can and are being obtained in the control and prevention of parasitism in the fish hatcheries. Some things which can be done are: (1) Obtain healthy breeders; (2) avoid overcrowding and its consequent weakening of fish; (3) give fish sufficient food and thereby develop enough vitality in the fish to resist better parasitic attacks; (4) prevent access of young fish to any chance infestation from adult fish; (5) study the life cycles of the fish parasites with a view to eliminating the intermediate hosts if possible; (6) develop new methods for treatment of parasitic attacks.

THE MOST VALUABLE TREE IN THE WORLD

By Lieutenant Commander P. J. SEARLES
NAVY YARD, BOSTON, MASS.

If one hundred Americans were asked "What is the most valuable tree in the world?" there would probably be a dozen or more different answers. But those who had lived in the tropics would be unanimous in replying, "the coconut tree." The coconut is perhaps the most desirable tree in existence as it provides food, drink, shelter and profit to millions; it can be made to serve innumerable necessary purposes; and without it the future of tropical lands would be dark indeed.

There is no necessity of describing the appearance of the coconut tree, as every one is familiar with at least the pictures of it. Every book with scenes cast in warm climes, steamship advertisements, Army and Navy recruiting posters, all use the coconut as pictorial propaganda. But, even though acquainted with its appearance, one can only learn by investigation and contact with the industry the multitude of uses to which the tree, its fruit and its leaves can be put. Let us consider somewhat in detail the value of the tree and how tropical people live by it.

The trunk of the coconut tree yields a timber (known in European commerce as porcupine wood) used for buildings, furniture, firewood, curios, etc. It is a light, spongy wood of low strength, which has found a wide use because of its prevalence. Houses built of this wood are not very lasting, but repairs cost only the labor, as the trees grow everywhere. Extensive use is made of the leaves for thatching roofs and sides of buildings; when well done, a good water-tight job results. The leaves are also woven into many kinds of baskets, cajan fans and other commodities and in some communities are even used as clothing after suitable preparation. Rafts and foot-bridges are among the uses to which the wood is put.

As food and drink the coconut is especially valuable. One's mind immediately considers the meat of the nut itself, but this is only part of the story. The meat is used somewhat, but to a lesser extent than commonly believed. It is usually eaten just as removed from the shell, although it may be kept for a considerable time and consumed in a rather sour, fermented state; or it may be prepared and put up in the grated form sold in groceries throughout the world. The meat is best when young and soft, in which condition it is frequently scooped out and eaten with a spoon. Not only is the meat an enjoyable human food, but chickens and hogs thrive on it. The young bud cut from the top of a tree gives one of the most delicious salads that can be found anywhere. It is a crisp substance like celery, but less stringy, and, of course, with an entirely different and indescribable flavor. It is variously known as "palm salad," "palm cabbage," or "palmetto."

The milk of the nut has a sweet, fresh taste, and is refreshing when drunk from an almost ripe nut on a hot tropical day. It may be taken at nut temperature or iced, plain or mixed with other juices, and is frequently used for a most enjoyable ice cream.

The juice of the tree, however, is much more widely used than the milk of the nut, and is a veritable treasure house. This juice is obtained from cuts

in the unopened inflorescence at the top of the tree, which may also (as in Ceylon and India) be bruised and pounded to accelerate the production. The resulting juice or sap is pathologically similar to the fluid produced by a sore on the human skin. The sap begins to flow in four or five days after the cut is made, and drips into vessels tied underneath the cut. In some parts of the world earthenware jars are used, although joints of bamboo are the most common. If the juice is to be used for alcoholic drinks, it is considered best to employ an old tube which contains the necessary ferments. It is a common sight to see an entire grove of trees connected by bamboo, somewhat like gutters on the roof of a building, all emptying into one or more huge jars. Each time a tree is visited an exceedingly thin slice is taken from the cut, using knives made especially for this purpose. In some localities the juice of red pepper is put on the cut daily to prevent insect attacks. From one to four quarts of the sap can be secured daily from a normal tree, the flow continuing for several weeks.

Fermentation of the sap starts as soon as it leaves the tree, and how far it is allowed to proceed depends upon the use to which it is to be put. The fresh sap, commonly known as "toddy" or "tuba," contains about five or six per cent. alcohol. It must be consumed at once unless, of course, a higher alcoholic content is desired. As ferment rapidly appears in the collecting vessels, it is necessary (in order continually to secure sweet toddy) to change the vessels daily, always using new and clean ones. In many parts of Polynesia, Malay, Java, Sumatra, etc., considerable sugar for home consumption is made from the toddy by putting into it a small quantity of some finely powdered bark which is rich in tannin. This crude sugar is occasionally refined into clean white sugar suitable for export; such a process is not commonly found, however, except in Java.

The most famous drink in the Orient for centuries is made by distilling the toddy. The resulting liquor is known as "arrack" by sailormen and "vino" by the Spanish; in a few localities it is called "aguardiente." It is a powerful drink, with, at times, over 50 per cent. alcoholic content, and is rather disturbing, temporarily and perhaps permanently, to the user. In many places in the Orient and the South Seas its manufacture is forbidden, but the process is so simple and speedy that it can not be stopped altogether, no matter how rigid the authorities. It is an aphorism of the tropics that prohibition is impossible in the vicinity of the coconut tree.

William Dampier, the old pirate (incidentally he was one of the crew of the ship which rescued Robinson Crusoe from his lonely island), knew of toddy and arrack as evidenced by an extract from his journal:

> Beside the Liquor or Water in the Fruit, there is also a sort of Wine drawn from the Tree called Toddy, which looks like Whey. It is sweet and very pleasant, but it is to be drunk within 24 hours after it is drawn, for afterwards it grows sowre. Those that have a great many Trees, draw a Spirit from the Sowre Wine called Arack. Arack is distill'd also from Rice and other things in the East-Indies; but none is so much esteemed for making Punch as this sort, made of Toddy or the sap of the Coconut Tree, for it makes most delicious Punch; but it must have a dash of Brandy to hearten it, because this Arack is not strong enough to make good Punch of it self. This sort of Liquor is chiefly used about Goa; and therefore it has the Name of Goa Arack. The way of drawing the Toddy from the Tree, is by cutting the top of a Branch that would bear Nuts; but before it has any Fruit; and from thence the Liquor which was to Feed its Fruit, distills into the Hole of a Callabash that is hung upon it.
>
> This Branch continues running almost as long as the Fruit would have been growing, and then

YOUNG COCONUT TREES

A FEW TREES GROWING WILD

TREES ALONG DUNCAS BEACH, GUAM

A LARGE COCONUT PLANTATION NUMBERING ABOUT 20,000 TREES

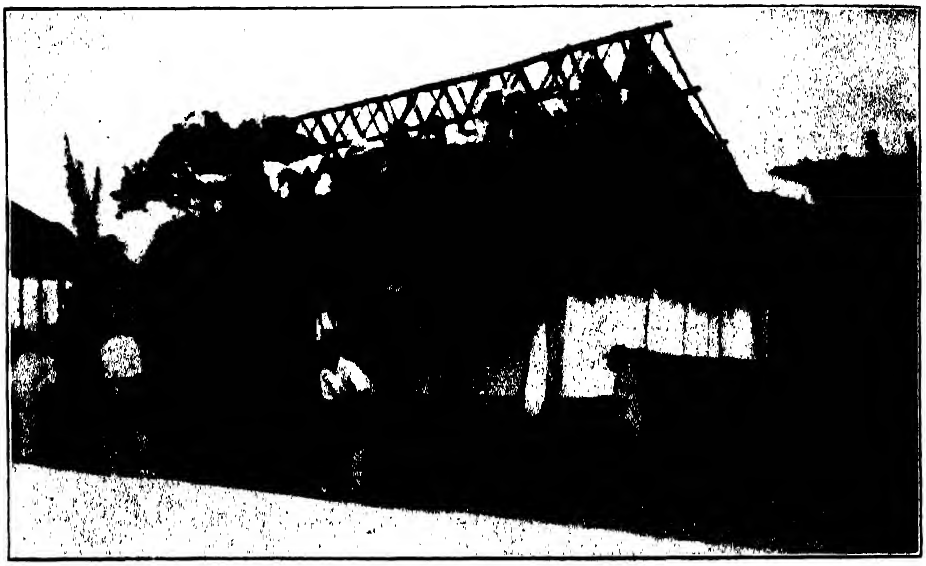
FREE-GROWN, NUT-BEARING TREES

it dries, away. The Tree hath usually 3 fruitful Branches, which if they be all tapp'd thus, then the Tree bears no fruit that year; but if one of the two only be tapp'd, the other will bear Fruit all the while. The Liquor which is thus drawn is emptied out of the Callabash, duly Morning and Evening, so long as it continues running, and is sold every Morning and Evening in most Towns in the East-Indies, and great gains is produced from it even this way; but those that distil it and make Arack, reap the greatest profit.

The above extract is from an account of the Island of Guam. This island, now a possession of the United States, is prohibition dry, but from the numerous arrests for violation of the eighteenth amendment it is evident that the coconut tree has not yet learned to obey the law.

Two other by-products of the sap are quite common, yeast and vinegar. In many communities no other yeast is ever used, even by transient white residents. In the making of vinegar special care must be taken to prevent putrefaction of the sap, either by the use of a bark rich in tannin, or by coating the containers with lime.

In a commercial sense copra is the most important product of the coconut tree. By copra is meant the dried meat of the nut. Usually the first step in copra making is the removal of the husk of the nut. In many Pacific islands the whole nut is split with a machete, although in a few places splitting machines are used. The milk must be thoroughly drained from the nut. The meat is rasped out in various ways; in the Philippines there is commonly used a "Kabyawan." This is a convex iron burr mounted on the end of an axis around which a cord is wound several times and run down at each end to a pedal. The burr bears teeth over its entire surface. The operator works the pedals with his feet, whirling the burr; the burr is pointed away from the operator, so that when he takes a half nut in his hand and draws it against the burr he can watch the removal of the meat.



THATCHING A ROOF, AGANA, GUAM

A SCHOOLHOUSE IN TALOFOTO, ISLAND OF GUAM, OF BAMBOO FRAMING AND COCONUT THATCHING

COCONUT TREES GROWING WILD ALONG THE OCEAN SHORE AND THE PAGO RIVER, GUAM

In many places the removal is done by a hand knife.

Immature nuts should not be used in copra making; the chief loss is not so much because poor copra (or less copra) is obtained, as because poor copra mixed with good copra lowers the market value of the latter. Copra from certain localities only commands half the price in world markets as copra from other places because of such mixture. Nuts cut from trees increase in yield of copra if allowed to stand in piles some weeks before being opened. Nuts that fall naturally from the trees are used at once.

There are several methods of drying the copra to remove the undesired moisture. Sun-drying requires from four to seven days of bright weather and produces high grade copra if not rained on. The best copra is produced by uninterrupted drying from the time the nuts are opened until desiccation is complete. It is important that copra should become surface-dried as soon as possible. This is done by opening the nuts in the morning, drying all day and sheltering at night. The sheltering is done in Guam by covering with mats woven of coconut leaves.

In some places the sun is relied on for preliminary drying up to the time of removal from shell, when subsequent drying is performed on grills or in kilns. In Tahiti, where the whole nuts are split, strips are then partially torn from the husk and by means of these the nuts are hung in the sun. In a few days the meat falls from the shells, and is then given a little additional drying. In most other lands (Cochin, for instance) the copra is laid on clean mats to dry.

Copra is also dried over free fires, thus receiving not only heat, but smoke and soot as well. The husks and shells of the nuts are frequently used as fuel, the entire process, of course, varying with local conditions and customs. The most uniformly good copra is made in drying-houses heated by steam or hot water; this method is followed particu-

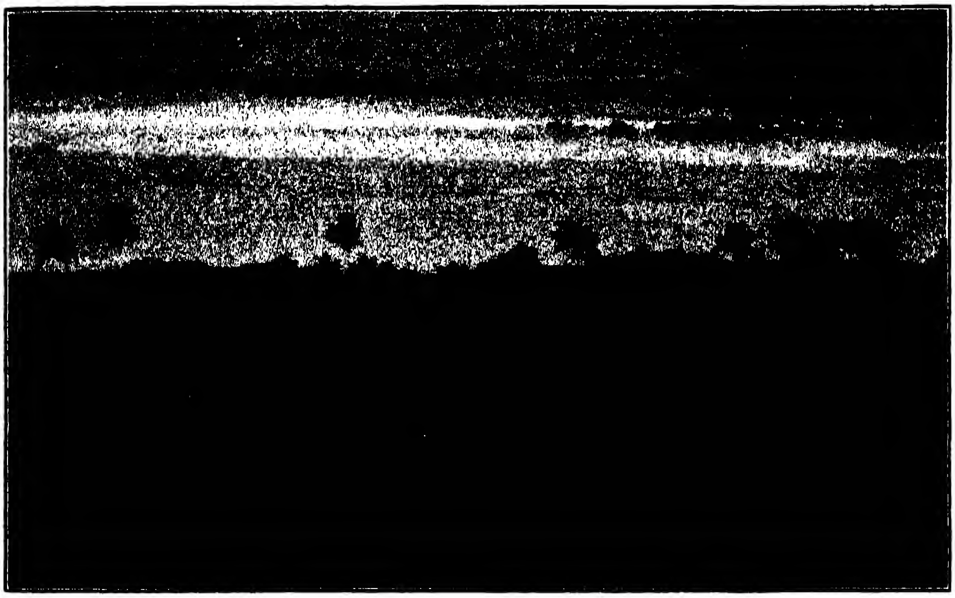
CHAMORROS OF THE MARIANA MAKING A MEAL OF COCONUTS

larly in Trinidad, Ceylon, and some parts of the Philippines. In the old German lands of New Guinea and the Bismarck Archipelago kiln-drying is common.

Most copra is shipped after drying to the United States and France, although there are a few oil-extracting plants in Ceylon, India, Mariana Islands, etc. In the factories the copra is thoroughly macerated by grating or scraping and grinding, and the oil is extracted by hydraulic presses or electrically-driven rolls. About twenty-five gallons of oil can be obtained from one thousand nuts. The oil is a white, semi-solid substance at ordinary temperatures, with a rather disagreeable odor (from the volatile fatty acids) and a mild taste. Under pressure it separates into a liquid and a solid portion, the latter, known as coco-stearin, being used in making candles.

What are the copra and oil good for? First consider the copra after the oil has been extracted. It is commonly known as copra meal, and is used widely as food for cattle and poultry. It is also of value for use in cakes and candies.

COCONUT TREES ARE EVERYWHERE IN THE TROPICS



SECTION OF A COCONUT PLANTATION

Sometimes it is made into a broth and soup for human consumption.

The oil is of more extensive utility and is a valuable article of commerce. It is used in the manufacture of marine soap, which forms a lather with salt water; every ship afloat carries a supply of this soap. The various grades of oil (which depend upon the maturity of the nut and the care in drying) are used for candles, high-grade soaps, cold creams, face lotions, shaving creams and other toilet preparations. The oil has both cleansing and lather-making properties. In the tropics especially the oil is used for dressing the hair; unperfumed this does not always lead to pleasantly odorous results, as a rancid smell soon develops. Oil obtained after fermentation has set in is used for candles and cheaper soaps. From the oil can be made an excellent waterproof polish for furniture, automobiles and other articles. Immense quantities of glycerine are obtained from the oil, this being a particularly important industry during the World War. Numerous butter and lard substitutes are obtained, some being advertised as coconut products. In England especially the oil is also used in the making of powdered milk. All these industries are of considerable importance, and all depend largely upon the coconut.

Another valuable and widely used product of the coconut tree is "coir." Coir is the commercial name of fiber prepared from the husk of the nut. It is used extensively for cordage, especially in the Philippines, and the Mariana and Caroline Islands. Among its many purposes are rope, fish nets, fiber for tying together parts of houses (which is desirable on bamboo and thatched huts in districts where earthquakes are frequent), caulking boats, etc. It is especially good as a caulking material, for it swells in water and makes a tight seam.

Coir rope is quite elastic, stretching 25 per cent. without breaking. It is durable, does not decay easily, but wears out rather rapidly because of the brittleness of the strands. It is very little used as textile fiber because of harshness, coarseness and brittleness, although

NOTE THE WAY IN WHICH COCONUT TREES ALONG THE SHORE ALWAYS GROW TOWARD THE WATER

clothing of coir can be found in many of the less civilized sections of the Orient and the South Seas. It is valuable for door mats, brushes of all kinds, stuffing for mattresses and other purposes.

The Laccadive and Maldive Islands furnish most of the European coir, although some is obtained from Ceylon and Cochin. Cochin-coir is the trade name for coir of finest quality. In making, the husks are macerated by soaking in water until the fibers can easily be freed from the waste matter in which they are imbedded. The fibers are then combed several times, washed, dried in the sun, combed again and sorted into the various qualities.

The shells and waste matter of the coconut are good for fuel, the former having a rather extensive use as charcoal. The shells are also valuable for fertilizer because of their potash content.

A few minor uses of the coconut tree remain to be noted. In many tropical countries spiral grooves are cut along the trunk of the tree and water is caught in a rain by flowing from the fronds along the grooves into a receptacle. The shells are widely used for water vessels, drinking cups, carved ornaments, ash trays, toys, curios, etc. In England, even, there is a rather popular county fair amusement, "throwing at the coconut." At times, also, a crude sail cloth made from the nut fibers is found on native boats in isolated places. In Saipan, one of the Japanese islands of the Pacific, coconut meat is used as a bait to lure deep-sea fish into surface nets.

What other tree can offer the varied uses of the coconut? Food, drink, shelter, clothing, toys for the savage child, curios for the tourist, illumination for the native hut, cosmetics for milady's boudoir, refreshing drink or hard liquor, rope or soap—all come from the coconut, the most widespread and most valuable tree on the face of the earth.

THE PROGRESS OF SCIENCE

THE EDGAR FAHS SMITH MEMORIAL COLLECTION

THE priceless collection of chemical memorabilia assembled by the late Dr. Edgar Fahs Smith, who was internationally known as a chemist and was provost of the University of Pennsylvania for ten years, has been presented to the university by his widow, Mrs. Margie A. Smith, and will be preserved intact in its present setting in the Harrison Chemical Laboratory, it was announced at the university recently.

With the acquisition of the collection, which will be known as "The Edgar Fahs Smith Memorial Collection in Historical Chemistry," the university is making special arrangements to safeguard it, following which it will continue to be accessible to visitors and students of the history of chemistry, many of whom, during Dr. Smith's lifetime, had frequent recourse to it for study and research work.

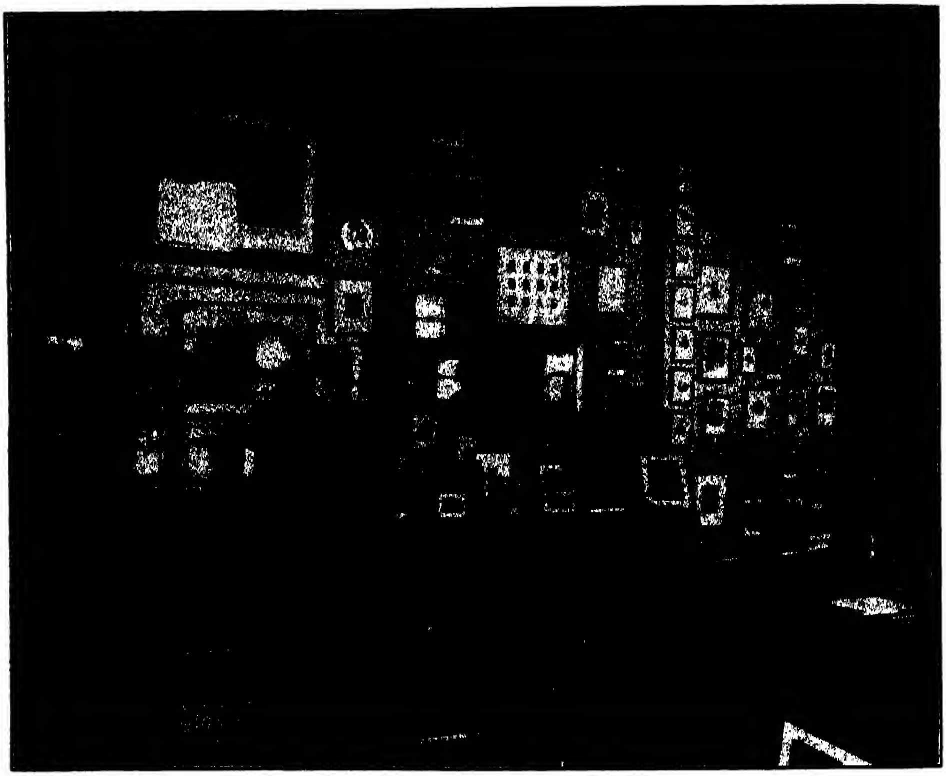
Eventually, it is expected, the university will create a fund, the interest of which will be devoted to the perpetual maintenance of the collection, and additions will be made to the collection from time to time, if possible, so that it may be an ever-growing asset to the chemical department of the university.

Dr. Smith, who died on May 3 this year, had served as emeritus professor of chemistry at the university after resigning the provostship in 1920. He was a former president of the American Chemical Society and of the American Philosophical Society, had served as a member of the United States Assay Commission; as trustee of the Carnegie Foundation, and as technical adviser to the Disarmament Conference, and was the author of more than 200 scientific papers as well as numerous books on chemistry. In 1926 he was awarded the Priestley medal bestowed by the American Chemical Society for outstanding achievement in the science of chemistry, and he also was the recipient of the Elliot Cresson medal from the Franklin Institute "for distinguished contributions to electrochemistry," and the Chandler medal from Columbia University for contributions to historical chemistry. In addition, France made him an Officer of the Legion of Honor "for distinguished services to chemistry." An appreciation of Dr. Smith, together with a portrait bearing his signature, were included in THE SCIENTIFIC MONTHLY for July.

Dr. Smith became interested in the history of chemistry early in his career and his private collection of chemical memorabilia, which is said by many authorities to be the best of its kind, was compiled during years spent in patient search in all parts of the world for rare items in which he was interested.

The collection, as presented to the university, comprises three main divisions. The first contains about 500 autographed letters and manuscripts of eminent chemists of all nationalities; the second is made up of approximately 1,000 portrait prints and engravings of prominent chemists from the days of the alchemists to the present, and the third consists of nearly 1,000 books on alchemy and chemistry.

In addition, there are a number of chemical preparations and a variety of chemical apparatus which Dr. Smith had accumulated during his career as teacher and research worker, and an unusually rare collection of books and manuscripts relating to the history of the University of Pennsylvania and the lives of outstanding alumni and members of the faculty.



THE EDGAR FAHS SMITH COLLECTION

Of Dr. Smith's collection of books on alchemy and chemistry the majority are in their original bindings and many are printed in Latin, German and old French.

The oldest book included is Geber's "Alchemy," which was printed in Nuremburg in 1545, while probably one of the rarest in the collection is the "Theatrum Chemicum Britannicum," printed in London "at the Angel in Cornhill" in 1652. This work was edited by Elias Ashmole and contains a series of old English poems on alchemy, one of which is by Geoffrey Chaucer.

Letters from eminent chemists of all nations from the earliest times down to those of Pasteur and Madame Curie are among the autographed manuscripts found in the collection. Notable among these is one addressed by Joseph Priestley in 1792 to a member of the National Assembly of France.

In this letter, Priestley accepts the honor which they do to him by making him "a citizen of France," but declines "nomination to the approaching National Convention."

Dr. Smith had long been interested in the life and works of Priestley and in 1926 had deposited in the Priestley Museum, at Northumberland, Pa., a collection of Priestleyana which was said to be the largest of its kind and which included Priestley's balance and the original manuscript of "Priestley's Memoirs."

Many of these items, as well as those in his collection of chemical memorabilia were presented to Dr. Smith by friends all over the world who were familiar with his zeal for collecting historical

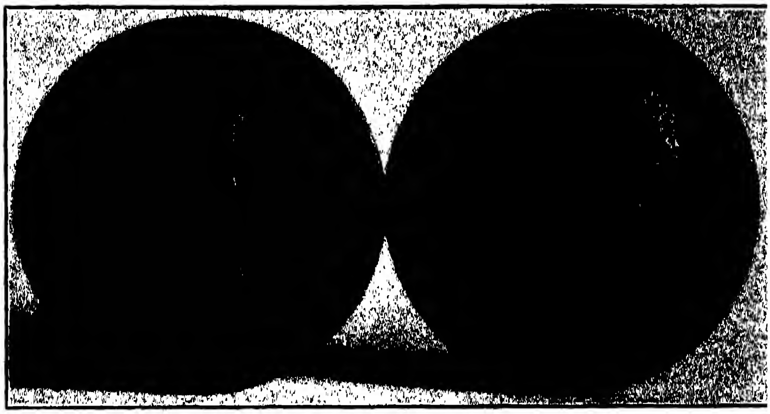
IN HISTORICAL CHEMISTRY

material, but the majority were found by Dr. Smith personally.

When the Harrison Chemical Laboratory was erected at the university in 1894, Dr. Smith selected two rooms in the laboratory for his offices and these rooms he continued to occupy until his death, making them the depository for his collections. As his collections increased, these two rooms gradually began to assume the appearance of a chemical museum, and as news of the variety and rarity of Dr. Smith's collections became known among chemists and others, the rooms became the mecca for students of the history of chemistry from all over the world.

So important did his treasure house loom in the eyes of chemists that when the American Chemical Society met in Philadelphia in 1926, an exhibition of historical chemistry was held in Dr. Smith's office and hundreds of chemists, including Professor Bertrand, head of the Pasteur Institute in Paris; Dr. Ernst Cohen, of Utrecht, Holland; Prince Conti, of Italy, and Professor Sapojnikoff, of Leningrad, Russia, were in attendance.

According to University of Pennsylvania authorities, a number of letters expressing the hope that Dr. Smith's collections would be preserved intact in their present setting and made accessible to interested students of chemistry have been received since Dr. Smith's death from men prominent in chemical circles. As a result, following Mrs. Smith's generosity in presenting the collection to the university, the work of fireproofing and otherwise safeguarding the rooms in the Harrison Laboratory which contain the collections is being carried on as rapidly as possible so that the collection may again be made available to those interested in research in the field of chemical history.



THE AWARD OF THE BENJAMIN G. LAMME MEDAL

THE first award of the Benjamin G. Lamme gold medal "for accomplishment in technical teaching or actual advancement of the art of technical training" has been made to Dr. George Fillmore Swain, of Harvard.

Dr. Swain has attained distinction as a thorough and practical engineer, an inspiring teacher and an authoritative writer. He received his technical education at the Massachusetts Institute of Technology and the Royal Polytechnic School of Berlin. Honorary degrees have been granted to him by New York University and the University of California.

PROFESSOR SWAIN

In 1887 Dr. Swain began his teaching work at the Massachusetts Institute of Technology. Since 1909 he has been a distinguished member of the faculty of the Harvard Engineering School. Dr. Swain has served as a consulting engineer for the Massachusetts Railroad Commission and has been associated with a number of engineering enterprises mainly in the field of transportation. His achievements have stood the test of time and his published works provide a means for extending his influence to the future.

The medal which has been awarded by the Society for the Promotion of Engineering Education was provided by the will of the late Benjamin G. Lamme, formerly chief engineer for the Westinghouse Electric and Manufacturing Company. It was Mr. Lamme's desire to advance the engineering profession by encouraging good technical teaching.

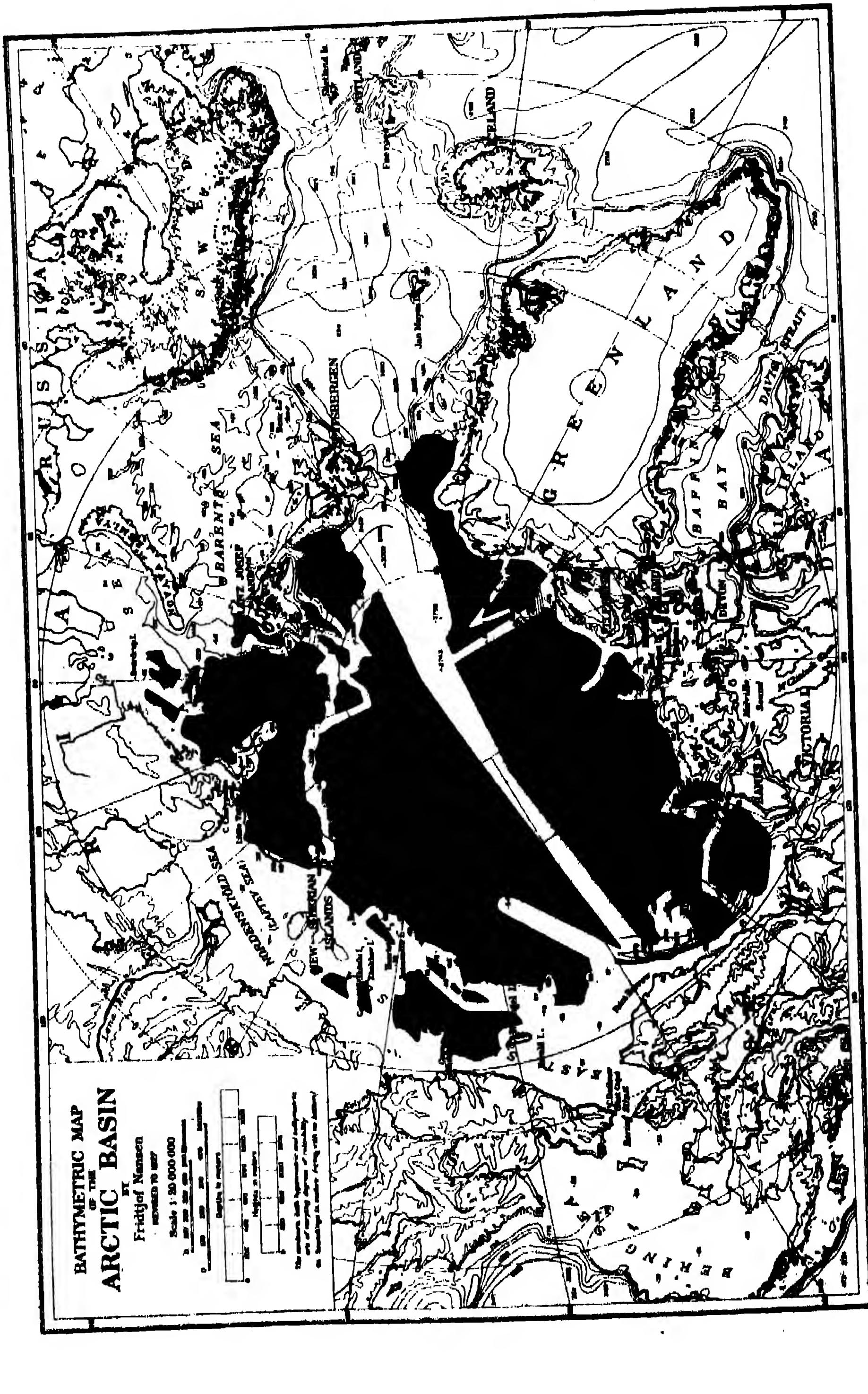
DR. FRIDTJOF NANSEN
WITH THE HON. H. H. BRYN, FORMER MINISTER FROM NORWAY TO THE UNITED STATES.

THE INTERNATIONAL SOCIETY FOR THE EXPLORATION OF THE ARCTIC REGIONS BY MEANS OF THE AIRSHIP

By I. P. Tolmachoff
Carnegie Museum, Pittsburgh, Pa.

The importance of aeronautics during the world war resulted in developments which have been found to be of great value in peace time. Flying machines heavier and lighter than air have already become regular instruments of transportation, especially in Europe. The wider application of flying apparatus to scientific and technical work is only a question of time. Even before the war the Russian government, in 1914, supplied its Arctic relief expedition with an aeroplane. During the war, aeroplanes were widely and successfully used as topographic surveying instruments. In different countries aeroplanes are now used in the fight against such agricultural pests as mice and injurious insects.

The national air connections soon were followed by the international ones. Not speaking of regular connection by air between different countries of Europe, the organization of regular air



DR. NANSEN'S BATHYMETRIC MAP OF THE ARCTIC BASIN

communication between the countries of the Old and New World is a task now confronting scientists and engineers. In spite of a number of disasters, the Atlantic Ocean has already been spanned with air routes. The Pacific, too, will soon be conquered. An examination of different possible air routes between Atlantic countries and those of the northern part of the Pacific showed that the shortest way leads through the Arctic. This route would run over the North Pole, or at least very close to the pole, over mostly unknown Arctic Ocean. The accompanying map shows very clearly these unknown regions, which, although they have never been explored by man, make about two thirds of the whole area of the Arctic Ocean. Not long ago this unexplored territory was even larger. It has been reduced to its present size through information obtained on recent flights to the North Pole, which, although undertaken without any special scientific purpose, have resulted in the discovery that a great strip of the Arctic is nothing but water surface. To make future flights over the pole safer, it is certainly necessary to explore these unknown areas, and this is one of the most important tasks of the new International Society. On the same map the route of a future expedition of the society is marked with a dotted line.

Germany took the initiative, but the enterprise finally resulted in the foundation of "the International Society for the Exploration of the Arctic Regions by means of the Airship," or, in abbreviated form, of the "Aeroarctic."

The official birthday of the society is October 7, 1924, although the preliminary work was carried on during several preceding years. Dr. Fridtjof Nansen, Arctic explorer, scientist and professor at the University of Oslo, internationally known as a political and social worker, was elected president of the society. His participation was a guarantee for the purely scientific purposes of the new society, and it soon secured a wide international recognition.

The central seat of the organization is Berlin. The society was received enthusiastically, and in a short time numbered two hundred members, elected among Arctic explorers and those connected with aeronautics or interested in the investigation of Arctic regions. The following countries are represented in the society: Austria, Bulgaria, Czechoslovakia, Denmark, England, Esthonia, Finland, France, Germany, Holland, Italy, Japan, Latvia, Norway, Poland, Spain, Sweden, Switzerland, The United States of America, and The Union of Socialistic Soviet Republics. In this list there are absent: Belgium, Canada, Greece, Hungary, Ireland and Portugal, but the three first-named countries have already been involved in the organization of local groups and perhaps should be included in the list. The present number of members is probably not less than three hundred, for it is daily increasing.

According to the statutes of the society, members belonging to a particular country, provided they are represented in sufficient numbers, may organize a local national group or branch. Such a group has just been organized in the United States. The officers of the American branch are: President: Dr. L. A. Bauer; vice-president: Dr. J. A. Fleming, of the Carnegie Institution in Washington; secretary: I. P. Tolmachoff, of the Carnegie Museum of Pittsburgh.

The financial means of the society consist of membership fees (at the present time an individual fee is $1.00 a year, that of an organization $5.00), donations made by friends of the society and appropriations by the governments. The last amount has been fixed accord-

ing to the population of the respective countries. Countries having a population below two millions pay $10.00 a year; two to ten millions, $50.00; ten to fifty millions, $150.00; above fifty millions, $300.00. According to this schedule the share of the United States is $300.00 a year.

Although still in the period of organization, the society has already begun its scientific activity. Its first and well-attended international meeting was held in Berlin, November 9–13, 1926. The next international meeting is planned for the approaching summer and will be held in Leningrad.

The society is already preparing an expedition to the Arctic in 1929. To own an airship and to supply it with the necessary material would certainly be impossible for any private society, even with greater financial means than the one in question. The German government, however, is apparently ready to devote one of its airships to this purpose. The Russian government has also promised to erect a mooring mast on Murman from which point the expedition will start its polar flight. The use of an expensive airship, and not of comparatively cheap aeroplanes, is dictated by the character of the proposed enterprise, which must be a scientific expedition aiming at various investigations, and abundantly supplied with all necessary apparatus, as well as having a large staff of scientists. The great number of these is demanded by the conditions of work. Passing over the Arctic would take only a few days, but the scientific work of the expedition will need to be carried on daily during the whole twenty-four hours, which is possible owing to the permanent day of the Arctic summer. This necessitates a triple number of scientists distributed in three daily shifts.

Besides this expedition the society is planning the permanent observation of the Arctic by means of a number of wireless stations which will encircle the Arctic Ocean, and which in their work will be closely connected with each other and the whole meteorological service of the northern hemisphere. The work of these land stations has to be supplemented by observations on the ice of the Arctic Ocean, made from temporary stations well supplied with a reliable staff, all necessary installations, provisions, etc. As means of transportation, flying apparatus will be used. This would also be able to bring relief to parties in case of trouble, which could be easily reported through the wireless.

In the month of April, 1928, the society began the publication of the quarterly magazine, *Arktis*, at the Justus Pertes publishing company at Gotha, Germany. Papers for the magazine may be written in English, French or German. The first number, for example, included two English and one French paper along with German articles. The international character of the journal is also shown by the distribution of its permanent contributors. According to a list published by the society, three of them are from the United States, two from Norway, two from Germany and one from each of the following countries: Austria, England, France, Holland, Russia, Sweden and Switzerland.

A new map of the Arctic regions, which will be published in many languages and which will be adapted to educational purposes, is being prepared.

Another task of the society is to work out and to perfect the technique of Arctic exploration, especially the construction of light wireless stations which could be easily adapted to transportation in flying machines. The fact that among collective members of the society there are such firms as Siemens & Halske and Siemens-Schuchertwerke shows that the new organization is well supplied with the technical forces, laboratories, instruments and financial means necessary for the purpose.

THE SCIENTIFIC MONTHLY

OCTOBER, 1928

THE FORMATION OF CORAL REEFS

By Professor W. M. DAVIS

DISTRIBUTION OF CORAL REEFS

CORAL reefs are rocky structures formed of the calcareous framework of various marine organisms, both animals and plants, among which the colonial polyps, known as corals, and the lime-secreting algae, known as nullipores, are by far the most important. These reef-builders flourish only in the warmer oceans and at moderate depths, the nullipores usually not below fifty fathoms and the corals not below twenty or twenty-five fathoms. In the torrid Pacific, cool currents from the south and north exclude reef-builders from the eastern third of the ocean; the middle and western thirds constitute the great coral sea of the world. In the torrid Atlantic similar cool currents reduce nearly the whole breadth of the surface waters below a temperature sufficient for the formation of reefs, which are therefore found in this ocean only along parts of the Brazilian coast and in the West Indies; the outlying reefs of Bermuda are as exceptional as is the great current of warm water, commonly known as the Gulf Stream, which permits them. Only in the Indian Ocean are the surface waters warm enough for reef-builders across the whole stretch of its torrid belt from Africa to Australia, evidently because Australia, unlike South America, does not reach south far enough to divert a great current of cold water toward the equator; but as islands are few in the eastern Indian Ocean reefs also are few there.

The minute larval forms of corals and the still more minute spores of nullipores are given off in myriads by the adult forms, and are drifted passively in ocean currents, where most of them are "food for fishes." If they happen to be carried to a reefless shore of firm rock or to a shallow bank where pebbles or shells lie undisturbed by waves in water of fitting temperature, they may there attach themselves, and by growing, multiplying and spreading, in time form a new reef. The living forms are vari-colored; their calcareous frame work is white; the reefrock is gray. The flat upper surface of a reef, lying close to sea-level, is narrow in the early stages of its formation, but it may later widen to half a mile or more. The flat is in some cases covered with reef-builders; in other cases it is almost barren. The outer face of the reef may either fall off abruptly, or may slope gradually to forty of fifty fathoms and then pitch steeply to great oceanic depths. It is chiefly on the upper part of the gentle slope, the so-called "growing face," that reef-builders flourish best. There, under the almost ceaseless beating of the trade-wind surf, the smooth, cloak-like nullipores serve an important part in binding together the more salient and less continuous coral growths. Darwin long ago noted that certain reefs are "protected by a . . . thick growth of Nulliporae on the outer margin, the part most exposed to the breakers, and this must effectually aid in preserving it

from being worn down." Nevertheless, blocks and fragments of reefrock, detached from the growing face by storm waves, are not infrequently thrown back on the reef flat, or shifted forward down the frontal slope until they come to the steep pitch where they descend to deeper water. The steep pitch may therefore be regarded as of talus-like origin.

Fringing Reefs

Coral reefs are of three kinds: fringes, barriers and atolls. Fringing reefs are sea-level flats, commonly from a quarter to half a mile wide, attached to the salient parts of continental or insular coasts, with their sea face falling off rather abruptly to moderate or greater depths. They are less developed in coastal reentrants, where turbid fresh water is delivered by stream floods; and they can not grow at all on sandy or muddy, bay-head deltas which, as they advance, may smother previously formed fringes. Reefs of this kind, openly exposed to ocean surf, are abundantly developed in the East Indies.

Barrier Reefs

Barrier reefs (Fig. 1), have, like fringing reefs, a narrow or broad flat and an outer growing face, but they are separated from the coast that they front by a smooth-floored, salt-water lagoon, from half a mile to a score of miles or more in width, and commonly from ten or twenty to forty fathoms in depth. Thus barriers have not only an outer face toward the open ocean, where the reef-builders grow most vigorously, but also an inner face toward the lagoon, where more delicately branching forms

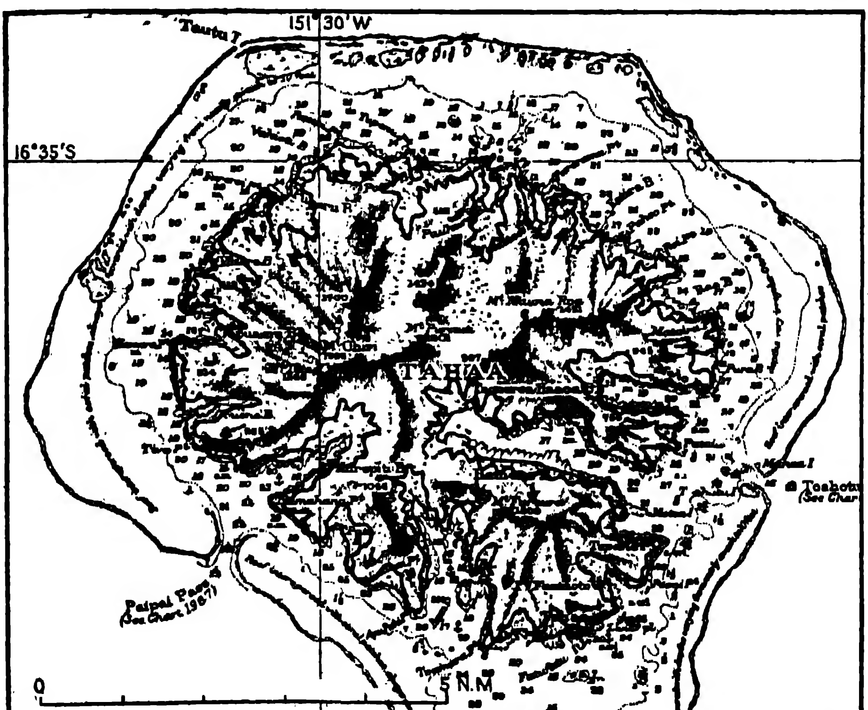


Fig. 1. Tahaa, a maturely dissected and well embayed volcanic island in the Society group, encircled by a barrier reef. From a Hydrographic Office Chart. A heavy line is added, back of the lagoon shore line, to show the very irregular initial shore line of subsidence, before partial bay-filling by deltas had taken place.

are found, if they are not overwhelmed by detrital inwash. The lagoon floor is usually rather smoothly strewn over with fine reef sand or silt, with detritus washed out from the coast, or with the remains of organisms growing in the lagoon waters or on the lagoon floor; indeed, the floor is sometimes covered with nullipores (Halimeda) which form a thick mat that has been compared to a peat bog. The inner shore of the lagoon is commonly occupied by a fringing reef, which is enclosed from the outer waves by the barrier reef. The growth of enclosed fringes is, however, not so vigorous as that of exposed fringes.

Barrier reefs are frequently interrupted by passages or "passes," through which ocean-going vessels may enter the lagoon. In narrow-lagoon barriers the passes usually lie opposite shore reentrants, as if in some way determined by the outwash of coastal streams. In wide-lagoon barriers, the passes on the windward side of an island-encircling reef are fewer in number than the reentrants of the shore, as if some passes that had originally existed had been closed by the reef-builders, for it seems to be on this arc of the reef that an abundant supply of dissolved oxygen and of food (plankton), brought by the wind-driven ocean waters, permits the most active reef growth. On the leeward side of such a reef circuit, the passes often open into broad breaches, presumably because of the unfavorable conditions there produced by the leeward drift of lagoon-floor sediments; for when the usually clear lagoon waters are agitated by storm winds, they become turbid, and at such times a considerable quantity of fine sediment is drifted out through the breaches into the open ocean.

The Great Barrier Reef of Australia

The longest barrier in the world is the Great Barrier Reef of the northeastern or Queensland coast of Australia. The patches and thickets of corals of this immense reef are finely illustrated in Kent's volume on the huge structure.[1] It is nine hundred nautical miles in length, with a lagoon from thirty to seventy miles in width, but of ordinary depth. Many small and large islands, the larger ones having well-embayed shores, rise from the lagoon of this enormous natural breakwater. The exposed outer side of the lagoon islands is relatively little cliffed, and the well-embayed coast of the mainland is not cliffed at all; this indicates a long-continued protection of the coast by the growing reef. But farther south, the cooler and therefore reefless coast of New South Wales, although likewise embayed, is island-free and strongly cliffed; and this indicates a long-continued exposure to ocean waves, while its inorganic continental shelf was forming off-shore. All along the east Australian coast, the former eastward extension of the mainland has been rather strongly submerged, apparently by down-flexing; in the north it appears to have been prevailingly reef-protected, in the south never reef-protected while the down-flexing was in progress.

Atolls

Atolls resemble barrier reefs in all particulars, except that no islands rise from their lagoon. The largest atolls are from forty to sixty miles in diameter; the smallest are less than a mile across, without a lagoon. Atoll reefs are rarely circular, usually irregular in pattern. Low islands of reef sand are often spread on the flats of barriers and atolls by waves and winds; they commonly become bush- and tree-covered, and are often inhabited; but they are exposed to the occasional danger of being overwhelmed without warning by earthquake waves.

[1] W. S. Kent, "The Great Barrier Reef of Australia," London, 1893.

Intermediate Reef Forms

The three classes of reefs grade into one another. An outstanding fringe, separated from the shore by a narrow belt of shallow water, resembles a close-set barrier. Some fringes gradually depart from the shore and become barriers; thus a fringe along the southeast side of Ngau, in central Fiji, becomes a well-offset barrier on the northwest side of that island. The central islands in certain barriers are so small, although still of mountain-top form, that the reefs may be called almost-atolls. Truk, a large encircling reef in the western Carolines, and Mangareva or Gambier, southeast of the Paumotus, are among the best examples of this kind.

Elevated and Submerged Reefs

All classes of reefs are found either elevated above or depressed below, as well as at sea-level. Elevated reefs are found abundantly in the East Indies. The large island of Timor bears many such reefs on its flanks, and a number of more or less dissected almost-atolls and atolls surmount its crest at altitudes of about four thousand feet; these are the loftiest reefs known. A fine elevated barrier, still enclosing a shallow lagoon, rises like an even-crested wall to a height of 180 feet along part of the northeast coast of New Georgia in the Solomon Islands. Vatu Vará is an elevated atoll of small diameter in central Fiji, 1,030 feet in altitude. The three Loyalty Islands, Mare, Lifu and Uvea, northeast of New Caledonia, are elevated atolls; the first two are evenly uplifted; the northwestern one, Uvea, is tilted to the northwest, so that its emerged southeastern arc has a somewhat crescentic outline, while its submerged northwestern arc is built up by new reefs. A fine submerged barrier, over two hundred miles in length, lies off the northwest coast of Palawan, the southwestern member of the Philippines. Two long stretches of a "sunken barrier" interrupt the great sea-level barrier reef that fronts the south coast of eastern New Guinea. Chagos Atoll in the central Indian Ocean, ninety-five by seventy-five miles across, is submerged to a small depth around nearly all its great circuit. Nearly a score of submerged atolls lie north of Fiji in the equatorial Pacific; their district may well be called the Darwin Hermatopelago or Sea of Banks. A deeply submerged reef seems to be indicated by a dredging made by the Siboga expedition in the Dutch East Indies; it brought up a haul of somewhat decomposed reef-building corals from a depth of over seven hundred fathoms in the Ceram Sea, thirty miles from the nearest land.

Darwin's Theory of Upgrowing Reefs on Subsiding Foundations

Three contrasted theories of coral reefs may be outlined, Darwin's, Murray's and Guppy's. Darwin[2] recognized that atolls might be occasionally formed as crowns on volcanic crater rims or submarine banks, wherever such foundations are provided at proper depth; but he rejected the idea, previously current, that all atolls are thus formed, not only because many atolls are not of crateriform pattern and are larger than the largest known craters, but also because it is inconceivable that volcanic cones should be abundantly built up from the deep ocean floor nearly to the ocean surface, without any part of the crater rim rising above sea-level. He explained barrier reefs (Fig. 2) by the upgrowth of fringing reefs, begun at small depth on slowly subsiding foundations, the floor of the enclosed lagoon between the reef and the receding shore being evenly aggraded with detritus from all available sources. Under this theory a barrier reef becomes an atoll when the central island of the barrier

[2] Charles Darwin, "The Structure and Distribution of Coral Reefs," London, 1842.

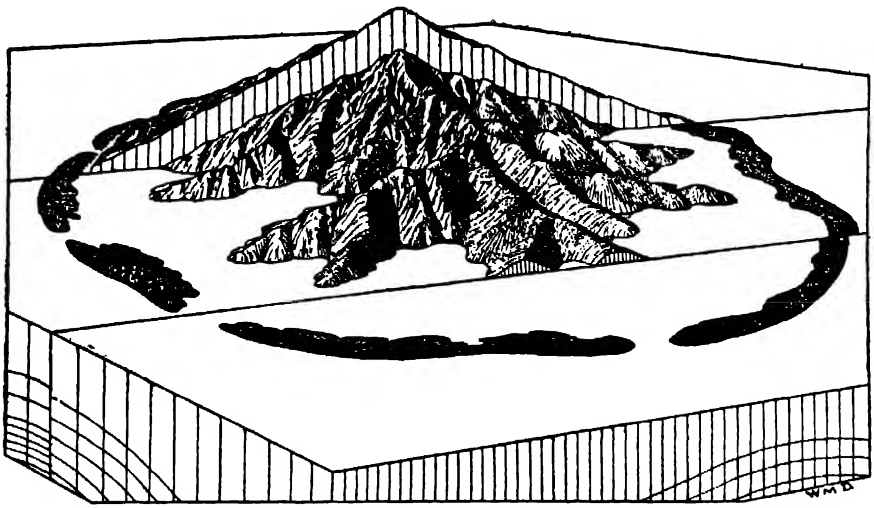


FIG. 2. A THREE-BLOCK DIAGRAM OF A SUBSIDING VOLCANIC ISLAND AND ITS UPGROWING CORAL REEF. BACK BLOCK, A FRINGING REEF ADJOINING THE CLIFFED SHORE OF A MODERATELY DISSECTED ISLAND. MIDDLE BLOCK, A BARRIER REEF ENCIRCLING A MATURELY DISSECTED ISLAND, WELL EMBAYED BY PARTIAL SUBMERGENCE. FRONT BLOCK, PART OF AN ATOLL ENCLOSING AN ISLAND-FREE LAGOON.

subsides below sea-level. Darwin associated fringing reefs as a rule with coasts of emergence, but he noted also that if a fringe or barrier be drowned by rapid subsidence, a new fringe, formed above the drowned reef, will rest upon a coast of submergence. He knew of no examples of such reefs, but they appear to be not uncommon in the East Indies.

MURRAY'S THEORY OF OUTGROWING REEFS ON STILL-STANDING FOUNDATIONS

Murray[3] rejected Darwin's assumed subsidence and explained barrier reefs by the outgrowth of fringing reefs on their own talus from stationary coasts; and he regarded the lagoons as excavated by solution of dead rock behind the advancing reef front, thus repeating an idea of Semper's (1863). Murray also suggested that atolls might be sometimes formed from barrier reefs by the degradation of the central island; but his preferred view as to atolls was that they are crowns upon banks that have been organically aggraded over still-standing submarine foundations, usually volcanic cones, of whatever depth, thus repeating an idea of Rein's (1870, 1881).

GUPPPY'S THEORY OF REEFS FORMED ON RISING FOUNDATIONS

Guppy believed that coral reefs are formed on rising foundations.[4] Atolls would thus crown shoaling but not emerged banks; barrier and fringing reefs would grow on or near emerged slopes. The lagoons of barrier reefs were explained by this observer as covering platforms cut by marine abrasion in coastal slopes during a pause in their emergence, thus repeating in essence an idea of Tyerman and Bennet's (1829), but without giving any reason for the failure of protecting reef growth while

[3] Sir John Murray, "On the Structure and Origin of Coral Reefs and Islands," Proc. Roy. Soc. Edinb., x, 1880, 505–508; also, "Structure, Origin and Distribution of Coral Reefs and Islands," Proc. Roy. Inst., xii, 1887, 251–262.

[4] H. B. Guppy, "The Solomon Islands, their Geology. . . ." London, 1887; also, "The Origin of Coral Reefs, Proc. Vict. Inst., xxiii, 1890, 51–68.

the platform was abrading, or for the cessation of abrasion after a platform of whatever width had been cut.

Points Omitted from Guppy's Theory

The inventors of these several theories adopted them without making a sufficiently thorough deduction of their consequences. Thus Guppy overlooked three significant points: (1) If fringing reefs are formed on rising coasts, they should lie conformably on non-eroded slopes; but most fringing reefs lie unconformably on slopes that had been subaerially eroded before the reefs were formed; thus showing that subsidence had preceded reef growth even if upheaval had later followed subsidence. (2) If barrier reefs rise from platforms cut in rising coasts, the shore back of them should be cliffed and not embayed, as in sectors H, J, K (Fig. 3), but such shores are in nearly all cases embayed and not cliffed, as in sector O. (3) If atolls are based on non-emerged shoals, their limestones should lie conformably on the non-eroded surface of the shoals; but several elevated atolls are known to rest unconformably on subaerially eroded foundations, which must therefore have sunk before the atoll limestones were laid upon them.

Points Omitted from Murray's Theory

Murray overlooked five significant points: (1) If narrow fringing reefs begin to grow outward from stationary coasts, they will in most cases be soon smothered by detritus washed out of the coastal valleys and swept along the shore by the waves, whereupon the reefs will be cut away and the shore attacked and cliffed. This argument serves also to contradict the suggestion that barrier reefs may be built up from whatever depth on the submerged flanks of still-standing islands; for in such case, the incipient fringing reef on the shore being smothered by outwashed detritus, the island would have a cliffed and non-embayed shore by the time the barrier reef was built up to sea-level around it; but the central islands within barrier reefs are seldom cliffed and are always embayed. (2) If fringing reefs should

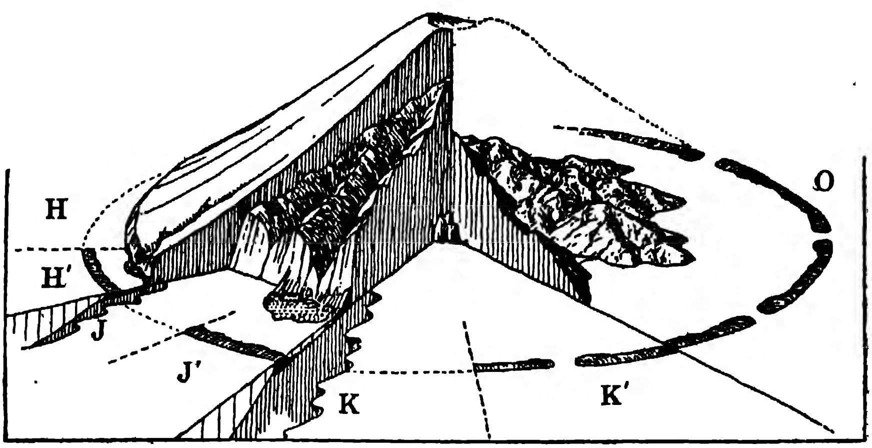


Fig. 3. Sector diagram, illustrating Guppy's theory of reef formation. Sector H, a slightly cliffed island; H', the same with a close-set barrier reef. Sector J, a strongly cliffed island; J', the same with a well offset barrier reef. Sector K, an almost consumed island; K', the same encircled by an almost-atoll reef. Sector O, a maturely dissected, well embayed, non-cliffed island, such as is usually encircled by a barrier reef.

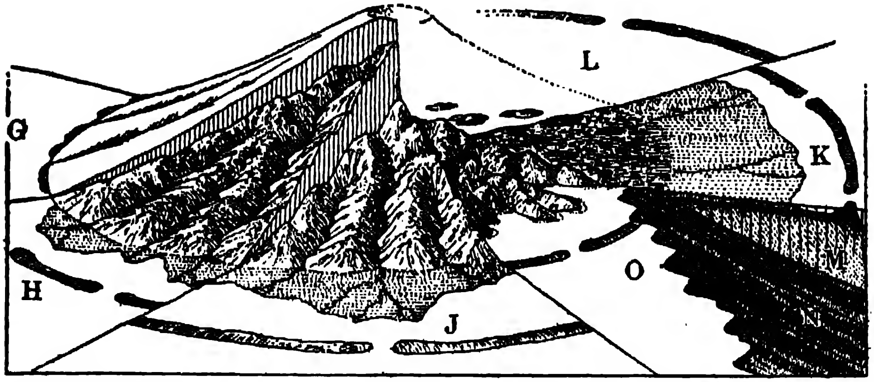


FIG. 4. SECTOR DIAGRAM, ILLUSTRATING MURRAY'S THEORY OF CORAL REEFS. SECTOR G, A FRINGING REEF ATTACHED TO A YOUNG VOLCANIC ISLAND. SECTOR H, A BARRIER REEF FRONTING A WELL DISSECTED ISLAND FRINGED WITH ADVANCING DELTA FLATS. SECTORS J, K, AN INCREASINGLY DEGRADED ISLAND WITH WIDER DELTA FLATS ENCIRCLED BY BARRIER REEFS. SECTOR L, THE LOW ISLETS OF A VANISHING ISLAND ENCIRCLED BY AN ALMOST-ATOLL. THE SUBMARINE SECTION OF SECTOR K SHOWS THE REEF-TALUS, M, RESTING ON THE NON-ERODED SLOPE, N, OF THE VOLCANIC CONE. SECTOR O, THE EMBAYED PATTERN OF ISLANDS USUALLY SEEN WITHIN BARRIER REEFS.

succeed in growing out and forming barriers, the stationary coast behind them will not be embayed, as it is in practically all cases. (3) If lagoons are excavated by the solution of dead-reef limestones, their floors, where not consisting of incompletely removed, bare and ragged rock, should be covered with insoluble residue, instead of being covered with accumulating calcareous detritus, as is commonly the case. (4) If barrier reefs are ever transformed into atolls by the degradation of stationary central islands, then the islets of almost-atolls should be low and flat, as in Fig. 4, sector L; but such islets are always of mountain-top form, as in Fig. 5, sector D. (5) If most atolls are crowns on organically aggraded, submarine banks, then elevated and dissected atolls should show pelagic deposits between a non-eroded volcanic base and the coral crown; but as a matter of fact only two elevated atolls—Roti in the Dutch East Indies and Barbadoes in the Lesser Antilles—are known to be underlaid by pelagic deposits; and in both of these islands the pelagic deposits lie unconformably on subaerially eroded, non-volcanic rocks, thus showing that island subsidence, at a rate too fast to be counterbalanced by reef upgrowth, had preceded a later and slower upheaval with reef growth and emergence.

Points Omitted from Darwin's Theory

Darwin failed to recognize three significant elements of his theory: (1) The disappearance of the great volumes of detritus that have been, in most cases, eroded from coasts fronted by barrier reefs, is best accounted for by subsidence. (2) If barrier reefs have grown up from slowly subsiding foundations, the coasts from which they are offset should be embayed by the partial submergence of the coastal valleys, as in Fig. 5, sectors B, C, E. (3) If the formation of barrier reefs and atolls is associated with the subsidence of their foundations, the lagoon limestones—but not necessarily the external talus deposits—should lie unconformably on the subaerially eroded slopes and summits of the foundation rocks.

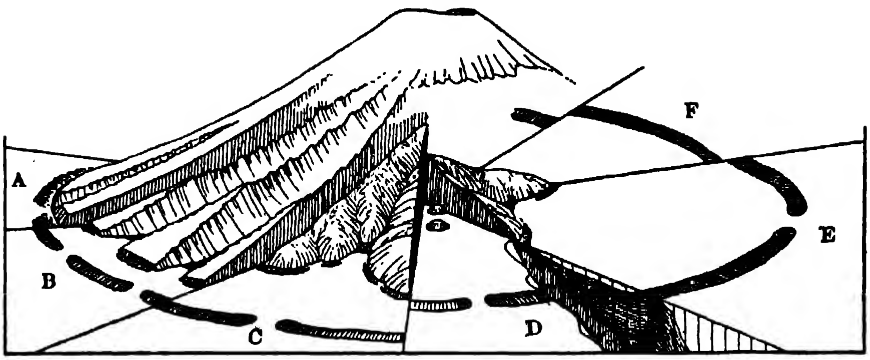


FIG. 5. SECTOR DIAGRAM, ILLUSTRATING DARWIN'S THEORY OF CORAL REEFS. SECTOR A, A FRINGING REEF ATTACHED TO PLUNGING CLIFFS OF SLIGHT SUBMERGENCE. SECTOR B, A BARRIER REEF FRONTING NEARLY SUBMERGED SPUR-END CLIFFS BETWEEN EMBAYED VALLEYS. SECTORS C, E, A MATURELY DISSECTED, REEF-ENCIRCLED ISLAND, SO WELL SUBMERGED THAT ITS EARLY-CUT CLIFFS HAVE VANISHED. SECTOR D, AN ALMOST-ATOLL ENCLOSING A LAGOON WITH RESIDUAL MOUNTAIN-TOP ISLETS.

CONFIRMATION OF DARWIN'S THEORY

But while the unnoticed consequences of Murray's, Guppy's and several other theories are strongly contradicted by the facts of observation, thus condemning those theories, every one of the unnoticed consequences of Darwin's theory is confirmed by the facts. (1) The volume of detritus that has been eroded from reef-fronted coasts would in nearly all cases have filled—often much more than filled—the reef-enclosed lagoons and overwhelmed the reefs, had the coasts remained stationary. (2) The central islands of barrier reefs are embayed, as Darwin knew; but it was Dana who first showed (1849) that such embayments necessarily result from the entrance of arms of the sea into the coastal valleys as subsidence progresses. Tahaa in the Society group (Fig. 1) is a typical example of an embayed island. (3) Elevated reefs nearly always rest unconformably on their foundations, as was first clearly pointed out by Walther in his study of the raised reefs of Sinai Peninsula in the Red Sea (1888). The elevated barrier of Mangaia in the Cook group of the Pacific has recently been shown by Marshall (1927) to rest unconformably on a well-eroded volcanic foundation, which must therefore have slowly subsided while the reef grew up around it. In the elevated atoll of Tuvuthá in eastern Fiji an unconformable contact of the reef limestones on a subaerially eroded volcanic cone has been reported by Foye (1918), who also found in the near-by Exploring Isles a similar relation between the limestones of several elevated reefs and their volcanic foundations. The association of subsidence with reef upgrowth in such cases seems unquestionable. Moreover, as these elevated reefs have been impartially selected for elevation, by deep-seated telluric forces of upheaval, they may be fairly taken as types of many barrier and atoll reefs which still lie at sea-level. Finally, if a theory involve various consequences not noticed by its inventor and if these consequences are confirmed by later-discovered facts, the theory is thereby strongly supported; and such is emphatically the case with Darwin's theory.

DALY'S GLACIAL-CONTROL THEORY

The novel glacial-control theory recently put forth by Daly[5] is based on

[5] R. A. Daly, "Pleistocene Glaciation and the Coral Reef Problem." Amer. Jour. Sci., xxx, 1910, 297–308; also, "The Glacial-Control Theory of Coral Reefs," Proc. Amer. Acad., li, 1915, 155–251.

the similar depth of reef-enclosed lagoons, which he believes can not be explained by the subsidence theory. He assumes that, as a rule, reef foundations have long been stationary; that many of the older volcanic islands of the Pacific had been degraded in Preglacial times to low relief with deep-weathered soils; that no barrier or atoll reefs but only fringing reefs were formed in Preglacial times; that with the coming of the Glacial period the ocean was lowered some thirty or forty fathoms by the withdrawal of water to form continental glaciers and ice-sheets; that even in the torrid zone the reef-building organisms were weakened or killed by the chill of the lowered ocean so that the ocean waves, first cutting away the dead reefs, then abraded the worn-down islands to low-level platforms; and that, as the ocean rose and warmed again in Postglacial time, barrier and atoll reefs grew up on the platform margins, enclosing lagoons at first everywhere of nearly uniform depth, although the smaller lagoons have later been much shoaled.

Invalidation of the Glacial-control Theory

This ingenious theory is largely invalidated by the various evidences of island instability above presented; also by the prevailing absence of cliffed shores back of close-set barrier reefs; for if many old, previously worn-down islands were completely abraded in the Glacial period, a fair number of less old islands should have been less worn down in Preglacial time and incompletely abraded in Glacial time, and such islands should to-day show partly submerged cliffs—plunging cliffs—back of barrier reefs; but islands thus cliffed are almost unknown in the coral seas. Yet as plunging cliffs do characterize a good number of islands that surmount imperfectly reefed banks in the marginal belts of the Pacific and Atlantic coral seas, it seems probable that Daly's factor of low-level abrasion—but not his postulate of island stability—there finds application. In this and a few other respects, Darwin's original theory, now ninety years old, may be, as I have elsewhere shown in detail,[6] modified to advantage, as follows.

Reefless Continental Coasts

Continental coasts of emergence are, as a rule, unfavorable to reef growth, because they consist of unconsolidated sediments; witness the Madras coast of India. Indeed, nearly all the torrid coast of the Indian Ocean west of the head of the Bay of Bengal is as reefless as the Madras coast: the near-shore reefs along a stretch of the east-equatorial coast of Africa have probably found their opportunity in association with a small submergence which has there interrupted the elevation that generally prevails elsewhere. Continental coasts of submergence are also unfavorable, if they are mountainous and rainy, as is for the most part the case with the coast of Asia from the head of the Bay of Bengal southeastward around the Malay peninsula and northeastward nearly to the delta of the Hoang-ho; for all along that embayed coast the outwash of detritus appears to be so abundant as to make the sea-floor muddy: even on outlying islands fringing reefs are rare around this long stretch of embayed continental margin. Many islands in the East Indies bear fringing reefs, as already noted, apparently because during the partial submergence from which many of them are now recovering, their abrupt shores expose much bare rock, instead of being cloaked, like the Madras coast, with loose sediments.

[6] W. M. D., "The Coral Reef Problem." American Geographical Society, New York, 1928. The illustrations of the present article are reproduced from this book.

Reefless Young Volcanic Islands

Young volcanic islands are also, as a rule, unfavorable to reef growth, because of the abundance of down-washed detritus which soon forms a beach around their shores, smothering incipient reefs and permitting abrasion; witness Reunion in the Indian Ocean and a number of reefless young volcanic islands in the East Indies. But embryonic fringing reefs may be locally and temporarily formed on the lava-flow salients of young volcanic islands, elsewhere beached and cliffed; witness Ambrym in the New Hebrides.

Reefs on Subsiding Volcanic Islands

Not until a young volcanic island has been more or less dissected and until its subsidence has disposed of the detritus eroded from it—the spontaneous or isostatic subsidence of a volcanic island being likely by reason of its great weight, as Molengraaff has suggested (1916)—will the submergence of its cliff-base beach permit reef growth to begin, either on the plunging-cliff faces or somewhat off-shore on the cliff-base platform. The Marquesas Islands seem to offer examples of incipient plunging-cliff reefs thus conditioned. Subsidence, therefore, appears to be essential not alone in disposing of outwashed detritus, but also in introducing the special conditions which permit the first successful establishment of young reefs and their further growth. In this respect Darwin would seem to have builded better than he knew. Yet if a long still-stand pause ensue after early subsidence and incipient reef growth, a new beach may in time be built up, whereupon the young reef will be smothered and abrasion will be resumed. Hence, not unless slow subsidence continues and maintains embayments in the coastal valley mouths, where down-washed detritus will be deposited in bay-head deltas, are up-growing reefs likely to persist. Even then, they may be after a time drowned by rapid submergence, as appears to be the case with a young barrier reef now submerged around the much-dissected and well-embayed island of Tutuila, Samoa.

The Plunging Cliffs and Barrier Reef of Tahiti

On the other hand, if subsidence continues at a moderate rate, the on-shore or near-shore reef may grow up as an off-shore barrier, enclosing a lagoon before the previously abraded cliffs are wholly submerged; and such seems to be the case of Tahiti in the Society Islands, where the many radial spurs between the deep-cut and partly submerged radial valleys are cut off in cliffs that appear to plunge below present sea-level. Yet here a somewhat prolonged still-stand pause, since the partial submergence of the spur-end cliffs and the accompanying embayment of the valleys permitted the upgrowth of the barrier reef, has caused the filling of nearly all the valley embayments with deltas, which have become laterally confluent and advanced somewhat into the lagoon, narrowing it and smothering many cliff-face fringing reefs. Indeed, even the off-shore barrier reef appears now to be somewhat endangered by the outflowing floods of muddy fresh water from the advancing delta flats. Further subsidence would drown the flats, widen the lagoon, re-embay the valleys, and rescue the barrier from the danger which now threatens it. Continued subsidence would in time completely submerge the spur-end cliffs, and the inter-bay spurs of the diminishing island would then slope gradually down into the widened, reef-enclosed lagoon. This stage appears to be already reached in the other members of the Society group farther to the northwest; for as one proceeds in that direction, the islands are found to be more and more dissected, and of smaller and smaller size, as if of earlier and earlier

origin and increasingly submerged; and still farther northwest the barrier-reef islands are followed by atolls, the island foundations of which have completely disappeared. Be it noted here that the cliffs of Tahiti should not be ascribed to low-level abrasion during the Glacial period, for in that case all the other islands of the group should also be cliffed, and they are not.

The Varied Reefs of Fiji

The Fiji Islands contain a greater variety of coral reefs than is to be found in any other group in the open Pacific. Indeed, in eastern Fiji, the association of fringes, barriers and atolls, both at sea-level and elevated, is so close that Darwin's theory has been held inapplicable there, even by so eminent a former supporter of that theory as Sir Archibald Geikie. But when the reefs of eastern Fiji are examined deliberately, it appears that Darwin's theory is really the only one that can reasonably account for them. It does so admirably on the not unreasonable assumption that the various changes of level which the eastern islands have suffered are due to the slow westward migration of a broad and low anticline with a preceding and a following syncline in the ocean floor.[7]

Coral Reefs in the East Indies

In the East Indies in general, recent movements of elevation and depression have been so active that typical sea-level barrier and atoll reefs are not often found there; but elevated reefs of various kinds abound. The moderate thickness of many elevated fringing reefs on the slopes of these islands has been illogically taken to argue against the correctness of Darwin's theory, which necessitates a great thickness for many barriers and a still greater thickness for many atolls in the open Pacific. But the proper interpretation of these thin fringing reefs, all of which rest unconformably on their island slopes, is that they represent relatively short-lived pauses in movements of upheaval or subsidence, which were at other times too

[7] W. M. D., "A Westward Migrating Anticline in Fiji." Amer. Journ. Sci., 1927.

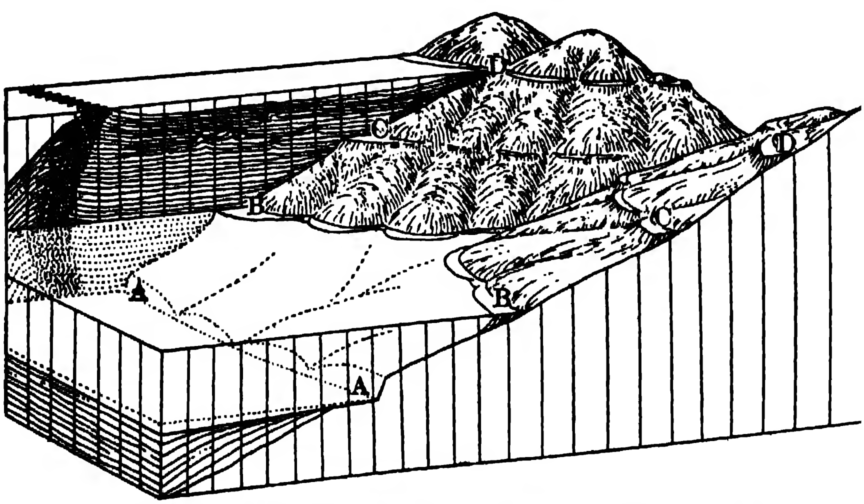


Fig. 6. Block diagram, illustrating the production of thin fringing reefs, B, C, D, in consequence of rapid changes of level in a subsiding and rising coast: in background, a heavy barrier reef and its thick lagoon limestones, formed by upgrowth on a slowly subsiding coast.

rapid to permit reef growth, as in the foreground of Fig. 6. Had the changes of level, especially the subsidences, which are there recorded taken place slowly, a fair number of barrier or atoll reefs one or two thousand feet thick would have been formed, as in the background block of Fig. 6.

The Atolls of the Open Pacific

The various groups of atolls in the open Pacific are to-day the most uncertain elements of the coral reef problem. They can be explained only by the aid of analogy with elevated barrier and atoll reefs elsewhere, as stated above: except that on Funafuti in the Ellice group a boring, made under the auspices of the Royal Society of London, to a depth of 1,184 feet—a small measure compared to the presumable thickness of the reef—has shown that shallow water organisms occur down to that depth in the reefrock, while deeper-water organisms occur at similar depths on the outer slopes of the reef; and this manifestly supports Darwin's theory. A number of reefs in Florida have been shown by Vaughan to have been formed at times of subsidence, but these are of small thickness and have little resemblance to the barrier and atoll reefs of the mid-Pacific.

Conclusion

In conclusion it may be said, in view of what is at present known of the coral reef problem, that in spite of the abandonment of Darwin's theory by many students of the subject in the past fifty years and notwithstanding the various obituaries that have recently been written over the supposed demise of that old theory, it is destined, when subordinately modified as above outlined, to regain in the next fifty years the general acceptance that it enjoyed through the middle of the last century.

COOPERATIVE FISHERY INVESTIGATIONS IN LAKE ERIE[1]

By ELMER HIGGINS
U. S. BUREAU OF FISHERIES

At the conference of biologists called by the U. S. Commissioner of Fisheries on February 6, 1928, at Cleveland, Ohio, the survey of research problems contributed by the individual participating investigators showed a remarkable unanimity of purpose. The central theme of each program of investigation submitted, the activating principle behind every project concerned the solution of the problem of conservation of Lake Erie's fisheries. It may be desirable, therefore, to review the principles and examine the field of study so that maximum progress can be made on the more urgent problems through the coordination of activities.

It is well established that certain of the fisheries of Lake Erie have suffered a material decline in productivity during the past two decades.[2] The more valuable food species have suffered most and the total yield of the commercial fisheries has only been maintained through a tremendous extension of fishing gear and effort and through the substitution in the market catch of less valuable or desirable species for the more popular varieties. But the decline in abundance of any species or of the fisheries as a whole has not been constant. The commercial yields, reflecting in a general way only the actual abundance of the fish themselves, has varied materially from year to year. The figures of the total commercial catch, however, can not be accepted as an index of abundance due to the interfering influence of environmental and economic forces. Changes in real abundance, involving both long-time and seasonal or short-time fluctuations, can not be determined at once from the data already existent, but variations in both abundance and composition of the fish stock must be determined by exact quantitative studies in order to discover the real trend and condition of the fishery.

As in the great marine fisheries, fluctuations in abundance of fish in Lake Erie are conditioned upon and explained by fluctuations in the age composition of the individual species, and these fluctuations in turn are due to the effects of diverse circumstances, such as, for example, changes in the environment by pollution of waters and increased mortality from commercial fishing. From a biological point of view the problems of the fisheries of Lake Erie are bound up in those fundamentals of growth and survival of each species, such as birth-rate, death-rate and migration or behavior.

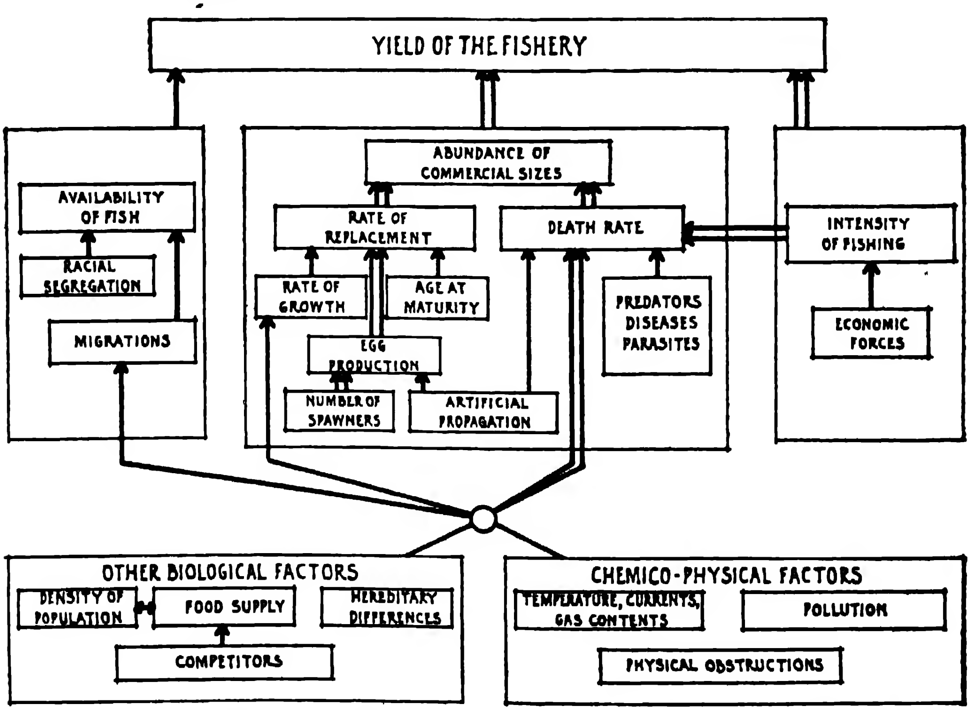
While the value of the fisheries of Lake Erie to the sportsman, the angler and the vacationist can not be disregarded and no attempt is made to minimize this value, the primary interest in the fisheries of Lake Erie is economic. Their chief value to the public at large is as a source of food and to the fishing industry—producers and distributors—as a source of profit. It is clear, therefore, that maintaining and increasing

[1] Published by permission of U. S. Commissioner of Fisheries.

[2] Statistics of the yield of the fisheries may be found in the various reports of the U. S. Commissioner of Fisheries and particularly in Document 1001, "Fishery Industry of the Great Lakes," by Walter Koelz. Appendix XI, Report for 1925, and Document 1025, "Fishery Industries of the United States, by O. E. Sette, Appendix V, Report for 1927.

the yield of the fishery is the fundamental and ultimate aim of any system of conservation and must form the central theme of any plan of investigation contemplating the application of results to human benefit. From a practical standpoint the most important question is, "How can we regulate the fishery or change conditions so that fewer adult fish are taken, fewer immature fish are destroyed and opportunities for the fish to reproduce are increased without seriously crippling the fishing industry?" Hence it will be proper to consider the various factors affecting the yield of the fishery and which are therefore worthy of investigation to discover their relationships and the relative importance of their effects.

The following diagram (Fig. 1) is offered as an attempt to define the relationships of the major fields of investigation, together with many of the minor factors influencing the yield of the fishery. An attempt has been made to present in graphic form a simplification rather than an elaboration of the elements of fishery science. Such a diagram can be extended indefinitely by the addition of details and no doubt may be simplified by reclassification and combination. Furthermore, no attempt has been made or could be made successfully in the present stage of development of the science to indicate the coordinate or subordinate importance of the many factors influencing abundance. It still remains to be determined by future investigations in each particular fishery which force or combination of forces exerts the dominating influence upon the yield. In the diagram the connecting arrows indicating the direction and relation of the interacting forces have



A GRAPHIC REPRESENTATION OF THE FIELD OF FISHERY INVESTIGATION SHOWING THE INTERRELATIONS OF VARIOUS FACTORS AFFECTING THE YIELD OF THE FISHERY.

been doubled in those cases which are believed to be most important, but even this is subject to complete revision with the accumulation of experience. In not all cases does the logical arrangement of factors indicate the proper sequence of investigation. It is hoped, however, that the diagram will be suggestive of both logical and practical relationships of the various problems and may indeed suggest short cuts to their final solution.

The yield of the fishery is directly dependent upon three major factors: First, the abundance of the commercial sizes; second, the availability of the fish to the fisherman; and third, the intensity of fishing effort. As biologists, we are concerned primarily with the abundance of the fish themselves, since such factors as growth rate, death rate, spawning and development, food supply, competitors, diseases, etc., together with the effects of physical features of environment fall within the conventional limits of biology. But as investigators in a field that may be characterized as *fishery science*, the other two factors affecting the yield of the fisheries, *viz.*, the availability of the fish and the intensity of fishing effort, must receive their share of careful consideration.

From a purely theoretical standpoint the factors of abundance and intensity of fishing are variables of the first order of importance in their effects on the yield of the fishery and in some fisheries, such as those for halibut or cod or salmon, they may include the entire range of effective influences. But from a practical standpoint in the case of the Great Lakes fisheries and the pelagic marine fisheries the varying accessibility of the schools of fish contributing to the commercial yield constitutes a factor of considerable significance. Although availability may be considered a phase of abundance, it is entirely distinct from abundance in that it is not directly affected by the intensity of fishing nor by rates of replacement or mortality. In this way racial segregation and migration, both seasonal and diurnal, have a real effect upon the commercial take without that theoretical bearing on abundance which is recognized by many as an important factor in the growth of populations. Since availability has a primary and direct effect upon the yield and is conditioned upon complex and obscure factors of the biological and physical environment causing migrations, it becomes a proper subject of inquiry by the fisheries investigator.

The third factor of first-order significance that affects the yield of the fishery is that of the intensity of fishing effort. It is obvious that the fish may be abundant and within reach of the fishermen's nets, but if the number of fishermen and the number and size of the nets employed is small the yield can not be great, and experience has taught us that a continued decline in real abundance can be entirely masked in the figures of the yield by an increased intensity of fishing. The yield of the fishery, therefore, varies directly with changes in the intensity of fishing.

The effects of commercial fishing upon the fish stock are extremely complex. In addition to its obvious direct relation to the yield it increases the death-rate and reduces the abundance of commercial sizes. Indeed, commercial fishing may be so extensive in certain fisheries, as proved by abundant evidence from the North Sea, the North Pacific and elsewhere, as to constitute the primary factor in increasing the death-rate. Furthermore, it affects the rate of replacement and egg production through direct attack upon the adult population composed of spawners. It produces material changes in the relative proportions of the different age classes in the population, in the density of population and possibly in the rate of growth and the age at maturity. These last-mentioned results, however, tend to pro-

duce a compensating effect in the rate of replacement. Indeed, the occurrence of the increased resistance to the strain of fishing at lower levels of abundance as shown in the halibut and plaice fisheries is explained by this acceleration in the rate of replacement resulting from decreased density of population and related increase of food supply. This increased resistance is probably a vital factor in the maintenance of the intensive fisheries of Lake Erie.

It is in investigations of the intensity of fishing that the biologist finds himself on the least familiar ground, for the factors that control intensity are almost entirely economic. Fortunately, the evaluation of the intensity of fishing is all that is necessary in understanding the effects of this factor on abundance of fish, but it is in the devising of fishery regulations that the economic questions must be most carefully considered and in this the fishery biologist must invite the collaboration of the business expert and the political economist.

Concerning the practical bearing on fish production in Lake Erie of other biological factors and of the chemico-physical factors of environment shown in Fig. 1, little can be said at present. It should be recognized that these influences are logically subordinate in importance to the three prime factors of abundance, availability and intensity of fishing, but until they have been specifically investigated with special reference to each important commercial species of fish, the practical significance of the various factors can scarcely be estimated. This does not minimize the desirability of conducting serious investigations of these subjects. They represent ultimate rather than immediate causes of variations in the fishery and as such may hold the key to the final solution of the problem of fishery conservation. As a basis of fishery regulations these more remote factors have added significance if it is assumed that the decline in the fishery is largely the result of changed physical environment, but they shrink in importance if the decline is due to over-exploitation of the fish stock. Since neither of these assumptions has been proved in the Great Lakes and since pollution and overfishing are both gravely suspected there is every reason for conducting inquiries into these causes of changing supply.

An investigation of the fisheries of Lake Erie may be divided into three branches or subdivisions which overlap but are essentially distinct in method, viewpoint, prerequisite training and personnel. The first is an examination of the yield of the fishery and an evaluation of the intensity of fishing for the purpose of determining the relative abundance of the fish stock of each species. Continued year after year this investigation will yield a true concept of the trend and condition of the fishery and provide many facts bearing on the biology of the fish that are useful in explaining the observed variations in abundance. The second includes a biological study of the fish, their life history, migrations, racial segregation, food, etc., which is essential to the proper interpretation of the study of abundance. The third branch is chiefly limnology, a study of the chemical, physical and biological features of the environment and the ecology of the larval fishes while they are a part of the plankton.

The practical operations in each of these three fields of investigation and the cooperating investigators of the various organizations interested in the biology of Lake Erie fishes may be listed as follows:

(1) The yield of the fishery and the intensity of fishing effort is being determined in New York state waters by the Bureau of Inland Fisheries of the State Conservation Commission, which has instituted a system of fishery statis-

tical returns furnishing sufficient information to yield an index of abundance of direct use to the fishery biologists. This system is similar to the one adopted by Michigan in September, 1927. It is understood that the states of Ohio and Pennsylvania, although no action has yet been taken, will institute similar systems and it is hoped that like action will be taken by the province of Ontario. As these records of yield and intensity in the various states accumulate through the years it is intended that the Bureau of Fisheries shall act as the central agency in assembling and analyzing them to determine the trend of abundance for the important species of the entire lake.

Of direct bearing on this study of abundance is the present work of the Bureau of Fisheries in defining and stabilizing the unit of fishing effort. To this end the effects upon the fish stock of the various types of commercial fishing gear, their efficiency and their destructiveness, is being investigated and recommendations for the most satisfactory types of gear will be issued to the various states.

(2) The life histories of the important species of fish are being investigated by the staff of the Bureau of Fisheries. The herrings, whitefish and pike perches are being studied first and other species will be investigated as personnel and facilities become available. The age and rate of growth, age at maturity, egg production, spawning and development and the age composition of the commercial catch together with the periods of greatest mortality in adult life are being fully investigated. The states of New York and Ohio and the province of Ontario are cooperating with the bureau in a study of migrations of adult fish by means of extensive tagging experiments at both ends of the lake.

The food of the important commercial species, together with their enemies, diseases and parasites, is being investigated by workers in Ohio and New York. Improvements of artificial propagation in increasing egg production and in reducing the death-rate in fry are receiving attention at the hands of the Ohio Division of Fish and Game through studies on hatchery technique in collecting and impregnating the eggs and in rearing and planting the fry.

(3) In the field of limnology and ecology, the states of Ohio and New York are assuming leadership. With the Bureau of Fisheries steamer, *Shearwater,* the Buffalo Museum of Natural Sciences is conducting an intensive study of the early life histories of fishes in the eastern end of the lake, together with the plankton communities in which they are found and upon which they depend. The chemistry and physics of the lake waters, the character of the bottom and the distribution of plant and animal life with specific reference to pollution and the obstruction of spawning grounds is also being given careful attention. A parallel line of investigations is being conducted by the Ohio Division of Fish and Game in the western end of Lake Erie. The New York Conservation Commission is conducting an intensive biological survey of the Lake Erie and Niagara River watersheds in which the biological contributions to Lake Erie will be fully investigated, together with the shore life, both plant and animal, within state waters. Certain aspects of fish food production on the bottom of the lake, together with detailed studies of the ecology of bottom organisms, will be conducted by investigators from the Western Reserve University, at Cleveland, Ohio, and the University of Michigan will aid in matters pertaining to technical ichthyology.

From the foregoing account it may be seen that the field of investigation is very broad indeed. Obviously there are many omissions and gaps in the plan

which must be filled in order to make a well-rounded program of research. This is but natural, since the various units initiated individual projects independently at various times and have only considered cooperative efforts at the single meeting at Cleveland. Closer coordination must, therefore, be effected through the conscious effort of the individual investigators to adopt comparable methods in attaining a common goal. As in all new investigations the greatest immediate needs are additional investigators and more funds, but it is confidently anticipated that from the enthusiasm of the workers now engaged the program will gain such momentum that other biologists in the Great Lakes region will join their efforts with the rest and that public appreciation of the nation-wide importance of scientific and practical results will assure adequate financial support from both state and federal governments.

ON RIGHTHANDEDNESS

By Dr. N. WILLIAM INGALLS
WESTERN RESERVE UNIVERSITY

"For he hath done marvelous things: his right hand, . . . hath gotten him the victory."

FEW questions of common biological interest can boast of so many and varied explanations as the age-old riddle of right- and left-handedness. Almost every conceivable influence has been invoked, at one time or another, and many of the alleged causes are so grotesque and irrational that one wonders if the authors were really serious in their attempts to find some adequate explanation. With the exception of a certain amount of evidence bearing on the inheritance of handedness, it can not be said that we know much more about the factors which really determine whether an individual will be right-handed or left-handed than did the person in whose mind the question first arose.

The question of handedness is essentially one which has to do with bodily asymmetry, with a certain more or less conspicuous functional inequality of the two sides, most manifest in the hands and arms. It is, therefore, not surprising that the search for etiological factors should have been directed almost exclusively toward other, often equally obvious, asymmetries or differences of the two sides of the body, in the hope that the question of right- and left-handedness would thereby be resolved or at least brought one step nearer solution. The most that can be said for these attempts, many of which have been very painstaking and exhaustive, is that they have brought to light an almost endless array of minor, not to say insignificant, asymmetries of all kinds in all parts of the body. A certain amount of interest may attach to this mass of information; certainly no one can doubt that the two halves of the body, right and left, are not, and need not be, alike or equal. Much has been learned which might have some bearing on the question at issue, while many findings are simply the results of, or are associated with, handedness, but in no sense can they be looked upon as causes. But still at the conclusion of the whole matter we are yet in the dark as to the reason why one person is right-handed and another is left-handed.

Our purpose at present is to call attention to what seems to us some very important aspects of the question; or, if one chooses, to a certain point of view which, as far as we can gather, has not received the attention it deserves. As will become evident later, we shall have nothing whatever to offer by way of explanation as to why one person should be right-handed and another left-handed. This is, of course, the classical question of right- and left-handedness, but in our opinion the nature of the subject is such that it should never have been formulated in this way. There are, in reality, two questions involved; one of these is of very fundamental biological importance and upon this it is possible to offer something concrete and constructive. The other question, on the contrary, is of secondary interest only; it is the classical question just referred to, upon which so much has been written and about which little or nothing is known. For our own part, not only is this latter question of very secondary importance, but we doubt very much if it admits of definite and final solution.

Before presenting our own views on

the subject, it may be well to inquire into the reality of the condition under discussion and also to cite briefly some of the various types of explanation which have been put forward, some of them very old, some comparatively new.

As regards the reality of the condition there is little call for argument. The very antiquity of the question and the variegated mass of literature which has grown up around it offer sufficient evidence that we are dealing with something real, with something, moreover, which demands an adequate explanation. More eloquent testimony, however, than mere lapse of time, more convincing evidence, indeed, than can be found in many a learned page, is scattered everywhere about us, meeting us at every turn. Language and convention, ancient or modern, sacred or profane, offer abundant proof that right is not left and that left is not right. From the solemn heights of a venerable ritual to the commonplaces of everyday life, our whole intellectual and moral fabric bears constant witness to the fact that we are the descendants of a race in which there was a heavy predominance of right-handedness. For this reason only are we "righteous," if such be the case, still lisping the language of a long forgotten past, when "right" was more concrete and tangible and when the distinction between the right hand and the left was still fresh and vivid in the fertile brain of our simple ancestors. If we interpret aright the wealth of linguistic evidence, if we may trust the hoary accumulations of tradition and all the myriad forms of habit and convention, we shall be prepared to admit that in that far-off day right and left possessed a meaning, a reality and a depth of significance utterly unknown to us. They must have stood forth in brilliant contrast, this superiority of one hand and the inferiority of the other; a contrast which could only be heightened, or hallowed, by the sheer weight of its antiquity and the utter ignorance of its real nature.

Primitive man lived and moved in a world of stern and intense reality; a child of nature, there was constantly unfolded before his wondering eyes a never-ending picture, colorful and concrete in the extreme; a picture, of which, in many ways, we possess now only a drab and faded counterpart. Not only did he find that one hand was a better and more obedient servant than the other, but in divers ways he was gradually acquiring points of view and developing certain mental and linguistic habits which were destined later to exercise an almost boundless influence. We reap to-day the fruit and flower, we gather in a harvest as varied as it is bountiful, but the seeds were sown long, long ago. Surely the better side of the body was a most fitting symbol of better things, of better conduct, and the better hand, the more trustworthy servant of the mind, finds its natural apotheosis in all the better things of life. Right was, and still is, essentially, a comparative rather than a superlative term, the better of any two things. So did the aged Israel, much to Joseph's displeasure, cross his hands in blessing, "guiding his hands wittingly" as the record has it, placing his right hand upon the head of Ephraim, who was the younger; his left hand upon the head of Manasseh, the firstborn — " . . . and he set Ephraim before Manasseh."

Few conventions of language, indeed of the human mind in general, can look back upon such a long, yet definite lineage, as the contrasting usage of right and left, in all its protean forms. There is a direct and uninterrupted line of descent down to the present, a line which began with the first dawning recognition of some real difference between the two hands and arms. Then and there right and left were born, where before there had been simply two sides, the one and the other, this side and that side; twin

prototypes they were, of good and evil, of better and worse, of right and wrong. With them, however, there crept into human affairs influences and reactions which cut deeply and sharply into the receptive mind of early man; elements, they were so charged with potentialities that they have colored all subsequent human history.

But this is by no means an isolated case of the development, out of little things, of deep and far-reaching ideas and persistent habits of thought. Other factors were also at work during this seedtime, and the foundations were being laid, widely, if not deeply, for much that was to follow. It were poor grace, indeed, to complain of the soil from which has sprung so much of beauty, so much of truth. If in that dim and distant past our groping forebears builded too often upon the sands, if much of what they reared thereon is threatened like mist before the rising sun, let us endeavor rather to understand than to criticize them and let us also be reminded that those same foundations have carried a priceless heritage for mankind.

Our ancient ancestor was impressed, and very deeply impressed, by other things than the difference between his two hands and arms. The very light which helped him to use those two wonderful instruments, the ever-welcome sun, which lighted and warmed the dark, cold recesses where he disputed tenancy with the cave bear and the grim wolf, left an indelible impress upon his whole mental make-up. Light and warmth, and the common source of both transmuted and transfigured his thinking as he in turn transformed the wolf into his most faithful companion. The air he breathed, the water, without which he could not live, and even the blood he spilled in many a mortal combat, all burned themselves so deeply into his innermost consciousness that all the intervening centuries have scarcely dimmed the record.

The other side of the picture is much more lightly drawn, and the opposite characters appear almost solely by contrast. The cold and darkness, the thirst and want, were real enough, but soon forgotten. Comparatively little attention was paid these rather negative things. With but one good arm, the other was left; a sort of poor relation, as it were, distinguished merely by never being right, always antonymic or derogatory. And so, perhaps, long, long after, it might have been some ironic justice of sinister fate which decreed that the left-handed Ehud should lose his sword in the ponderous form of Eglon.

After this digression, which may serve as a part of the background, we may note in passing a few of the explanations which have been offered in regard to right- and left-handedness.

It is not necessary to go farther back than Plato, who supposed that the condition of right-handedness was due to the child being carried on the mother's left arm, but a little thought will convince one that the argument may be used either for or against this view. Quite as old, perhaps, and always popular was the idea of the protection of the heart by a shield on the left arm. In both cases, however, we are obviously dealing with effects and not with causes. Some writers have cut the Gordian knot and supposed that it was a question of training and early education or even a childish obstinacy and opposition to instruction. Although it is doubtless true that there are varying degrees of handedness and that much can be accomplished by training and use, there is, nevertheless, every reason to believe that the condition of handedness was established in a very remote past and that it has come to be such an ingrained characteristic of man that no opportu-

nity is now afforded to reopen the question, beyond the small choice of either right or left. The underlying causes of handedness are to be looked for in the past, not in the present. Heredity, regardless of the rôle it may now play, is silent and helpless as an explanation.

Since handedness appears as an asymmetry of the body, it was natural to look for other asymmetrics which might explain it. The heart is on the left side; the center of gravity of the body is a little to the right of the midline; the two halves of the brain are not alike, or do not receive the same amount of blood; the hands and arms may be quite dissimilar, and so on down through the long list of variations between the two sides of the body. Indeed, the very number and variety of the solutions offered would indicate that there is little unanimity of opinion as to the real nature of handedness.

A comparatively late and loud claimant for the honors in this field is the doctrine of ocular dominance. Its chief supports are represented by two quite untenable assumptions. One is that there is a fairly constant and material, qualitative difference in the two eyes, as visual, optical instruments, the right eye being usually the better eye. The other idea, reminiscent of medieval biology in its naïveté, is that each eye controls the corresponding side of the body. The reasoning is simple and sound, the right arm is the better because it is under the direct control of the better eye; the premises, however, leave much to be desired. It is a matter of common knowledge that in using one eye alone there may be a decided preference for one rather than the other, but this choice is not proof of better vision nor does it even correspond essentially with the choice of hands as expressed in handedness. Nature did not spend untold centuries in developing an adequate binocular vision and all the intricate nervous mechanism which goes with it, and then, when the task was done, close one eye and use the other; or even allow the body to be guided and influenced by one eye more than by the other. Without doubt vision has exercised a most decisive influence in the development of the human faculties, but nature has played no favorites with the eyes, they have always been and still are, to all intents and purposes, equal; and, then as now, two eyes were better than one.

We need not be unduly disturbed if the two sides of the body are not exactly alike. Rarely, if ever, in dealing with animate forms does nature achieve a perfect, complete geometrical symmetry. She is, of course, much more interested in function, and slight or even more marked deviations from formal perfection may be of little or no consequence. In the bilaterally symmetrical animals, of which man is a representative, we should not expect a degree of likeness or similarity between the two sides beyond that necessary to guarantee proper and harmonious function. Absolute, mathematical symmetry is not called for.

Notwithstanding all this, however, we have to remember that *asymmetry* has often been a most important method of attaining invaluable functional qualities. Times without number, and in the most unexpected places, asymmetry confronts us as one of the cardinal points in *specialization*.

It is with handedness as a *specialization* and a sign of progress and higher organization, moreover as a distinctly human and relatively late specialization, which we have to reckon. It is to this view of handedness that we would direct attention.

Handedness, either right or left, is something quite different from the numerous other bodily asymmetries, with which, however, it is often confused and from which so many fruitless attempts have been made to derive it. It

belongs, on the contrary, in a much higher category, since it connotes a definite and important functional superiority of one upper extremity as contrasted with the other. It is not something passive or purely receptive, something resident in the real or supposed superiority of any percipient organ, but rather something active, integrative and creative. It finds its peculiar office in the *use* made of the contributions of the senses, and in the *services* rendered thereby; for faith without works is dead.

As previously noted there are two aspects of the subject under discussion. One, by far the more important of the two, concerns the problem of handedness *per se*. The other side of the question, not only of little moment but also exceedingly obscure, is why the choice in handedness falls now on one side of the body, now on the other, more commonly on the right. The point at issue is not, primarily, why one person is right-handed and another left-handed, but rather why he is handed at all, why one arm and hand, quite irrespective of which one it may be, is materially and significantly better than the other, why the difference, why the asymmetry; what value or advantage, be they ever so little, could have accrued to the possessor of one good and one better hand as compared with the doubtful merits of a double mediocrity?

But, strange as it may seem, it is the second question which has claimed the undivided attention of practically every writer who has given the subject any consideration. Only rarely does one encounter even a passing allusion to the larger problem, first by Sir George Humphrey and later in the writings of Elliot Smith.

Handedness is to be looked upon as a specialization, it was one of the harbingers of a new epoch in the history of life, announcing the dawn of the psychozoic era. Since, however, we have two hands and arms, specialization automatically and inevitably leads to differences between the two, in other words to asymmetry of one kind or another. Over and over again, nature, in dealing with bilaterally symmetrical organs, has specialized one at the expense of the other, even doing away with one entirely.

Although handedness is a very convenient and expressive term, it would be more accurate and to the point to speak of brainedness, either left or right. The functional superiority of one limb is essentially dependent upon the functional superiority of that part of the brain which controls and guides it. For the right arm and hand this is the left side of the brain, and for the left arm it is the right side.

The question comes back, therefore, to a specialization of one side of the brain, which would, of course, express itself in the opposite side of the body, in this case in the arm and hand. That portion of the brain concerned is, like the limbs, a bilaterally symmetrical organ, and, consequently, specialization involves the choice of one and only one side, and that more or less at the expense of the other.

This specialization of one side of the brain does not apply to either side in its entirety, but it is restricted in its sphere and range of influence to certain of the newer and more highly organized functional areas of the brain. The reason for this is that it is concerned not so much with the reception of stimuli as it is with their elaboration into appropriate reactions. It is not so much that which comes in as that which goes out; not so much any increase in the extent, variety or precision of sensory impressions, but rather a more thorough integration and correlation of the information already at hand and its translation into new motor responses and finally into creative activity. This significant difference in the two sides of the brain, a certain more or less con-

spicuous superiority of one over the other, is an essentially human characteristic, the last great step forward in human development.

Why, however, most people are right-handed, or rather why, long ago, the left side of the brain gained a slight but effective ascendancy over the right in the majority of cases, we do not know. It is easy enough to grasp the significance and value of the principle of handedness, but what is there to decide the choice between right and left? Certainly the outside world, man's immediate environment, could not have put greater demands upon, or favored, one side of the body rather than the other. On the other hand, there is little or nothing apparent in his own make-up at all calculated, as far as we can see, to throw the choice either to one side or to the other. That the choice was made is perfectly obvious; it would seem, indeed, that it could not have been avoided, and we may never know, at this late day, just why the lots fell as they did. It is altogether possible that very minor, in other respects, quite insignificant factors, might have turned the tide one way or the other; it is not even necessary to suppose that these influences were always the same or that they were always acting upon the same kind of a nervous system. They may have been merely the dust of the balance, as it were, but they contributed some small though signal advantage, and that at a time when little things were weighing heavily in the long upward struggle for the final supremacy of mind over matter.

In the great economy of nature, in her making possible and in her furtherance of human progress, with two sides of the body, with two arms and two hands from which to choose the instruments with which man should work out his own salvation, it has been her way that "the one shall be taken and the other left."

This newer, higher specialization of the brain,. which goes under the name of handedness, presupposes a long line of antecedent development, an extended period of conservation and preparation before even the necessary seeds could find a suitable soil. It is not necessary to trace in detail this line of development or to attempt to define its relation to geological landmarks. Man is by no means the last arrival on this humble planet, the final, sudden flowering of the tree of life; unnumbered generations have contributed their modest share; little by little, step by step, he slowly and almost imperceptibly takes form out of the depths and darkness of a past whose antiquity we have only lately learned to appreciate.

If we go back far enough, and it will be many millions of years, we may pick up his trail as a little furry form, spending the short span of his precarious existence close to the ground or at times even underneath it. Guided largely in his little life by the lowest and most uninspiring of the senses, smell, he nevertheless embodied within himself a certain plasticity and adaptability of structure and character, and a stability and primitiveness in organization which were of the utmost importance. Attracted by higher things, he forsook the ground and took to the trees, a most momentous change. That leaving of the ground was a last exodus from the hard bondage of the lowest senses and the meaner things in life, for it is utterly impossible to build up a respectable nervous system on smell and taste alone. Subservience to these senses and submergence in what they have to offer forever shuts out the animal from better things, tying him down to an ever-narrowing life or leading him into the fatal cul-de-sac of some protective or adaptive specialization.

Once well in the trees a new world opened before him. Sight, instead of smell, became the dominant and guiding influence in his life. The peculiarities of his new environment were admirably adapted to call forth the best that was

in him; to enlarge and perfect his vision, to enhance his native nimbleness and agility, as well as to sharpen his wits and enlarge and quicken his resourcefulness. And thus there were gradually unfolded through the coming centuries those innate potentialities which his simple organization and freedom from specialization had preserved. It was to vision more than to anything else that he owed his steady upward climb, as it was a figurative vision which was later to lift him higher and higher, giving him a broader and deeper outlook until at last he should be able to see himself in his true relation to all the world around him. Back of the eyes with their ever-increasing efficiency was a brain capable of encompassing the great variety of impressions offered, and, furthermore, capable of responding to them with rapid growth and with a constant increase in the facilities for retaining, reproducing and elaborating the complex information received. The body grew very materially in size and strength; a host of minor modifications made their appearance, while the proportions of the body were altered in conformity with newer postural habits to the immense advantage of both receptive and motor faculties. But the most conspicuous advantage of these later postural habits, or rather, one should say, of the newer attitude of the animal toward his environment, accrued to the brain. The gradual assumption and establishment of the upright position, the liberation of the arms and hands for newer and more varied activities, and the opening up of wider and more alluring fields for the exercise of his native inquisitiveness, provided alike the opportunity and the stimulus for the final stages of his development. But this opportunity and this stimulus would have availed nothing, and the crowning features of mental development would never have been realized, except for the long, preparatory period of brain development which went before. Escaping the withering influences of the lower senses, and preempted early by sight and touch, the brain had already served a long apprenticeship to these higher senses, as it had also grown and expanded under their guidance until it was finally fitted to reap the full benefits of the information and knowledge which those senses alone could provide.

Just when our little ancestor began to be weaned away from a largely arboreal life, we do not know, nor are we at present concerned with the motives which may have prompted him to exchange, at last, the comparative quiet of his leafy home for the dangers and excitement, and also the opportunities, of terrestrial life. His sojourn among the trees had completely transformed him, he had waxed strong and confident, both in body and mind; quick and keen, he returned to his birthplace and to his birthright, admirably equipped to cope with whatever the future might have in store for him.

But most important of all, he brought into this new life an exquisitely adapted mechanism with which to meet and mold his environment, something with which he could literally and figuratively take hold of and grasp the things around him, shaping his own fortunes like clay in the potter's hand. These instruments, which would either make or break for him, were his hands, his most precious possession, for without them the brain and mind would have remained forever silent and sterile. Only through the instrumentality of his hands could he have developed his brain, and only through his hands could his higher faculties have found adequate and necessary expression. The two are inseparable; the brain presupposes the hand, and the mind of man without the hand of man is unthinkable; so hands without the mind are as vain and empty as sounding brass and a tinkling cymbal.

Few, if any parts of the body, have remained so comparatively unchanged through countless centuries as the

hands. Among the earliest footprints which have come down to us, we recognize at once the typical five-toed form; footprints left in the mud or sand at the water's edge, by some slow-moving, uncouth form which left its watery home to warm its cold blood in the summer sun, and thereby staked out the first claims for the domination of the land by higher forms of life. To that primitive five-toed pattern, as if there were something sacred about it, nature has held with the most remarkable tenacity. Never once, in the long, slow climb from those cold, muddy, all but senseless feet to the hand of man, has there been any material deviation from the original type. Never once has there been any sacrificing or compromising of its general usefulness and almost universal adaptability, for the sake of special efficiency in some restricted field.

Man's feet and legs, on the contrary, have undergone considerable alteration, to the end that they might better support and carry about his head and hands and provide a convenient basis for the use of his arms. They only are specialized, not his hands and arms. And so it comes about that, for taxonomic purposes, he is distinguished almost exclusively by his brain and his feet.

The hand, then, in its essential features, is vastly older than the brain which now commands it. For untold ages it had been lying fallow, as it were, like so many other treasures in nature's storehouse, awaiting only the "Open Sesame" of the human mind. But in the fullness of time that hand was to come into its own and become the living symbol of creative power.

Somewhere, somehow, the curtain slowly rises on the most momentous scene in all the long life history of the earth. From out the uncouth throng which crowds the stage, a single, halting form appears, man; the chief, if not the sole actor in all that is to follow. For many weary centuries he had been struggling to learn his first few, simple lines. Long had he eaten the strong meat of elaborate and inspiring sense impressions, visual, tactile and auditory; long had he contemplated, in his little way, the wondrous world around him; but now the time was ripe for better things, the field was white to the harvest, the kingdom of the mind was at hand.

The day had dawned when that new brain should find something for those old hands to do, something they had never done before, for never before had they been under the spell of such a brain.

As to the nature of these mental and manual activities, we can only speculate. The material evidences of these feeble, faltering attempts to mold the outside world to match the inner thought; these first, prophetic fruits in the garden of art, have, like their creator, vanished completely. They were the expression of the newest and highest faculties, giving evidence of themselves primarily and most typically in the use of the hands and arms; in those activities, moreover, whose highest and finest development not only made possible, but even demanded, commensurate development of one side of the brain, its specialization, in other words, to carry out its own behests. Although it may not be possible to reconstruct those early scenes, or to determine, except in the vaguest outlines, the modes of expression of the nascent intellectual powers, it may, however, be possible to say what they were not.

They are not to be sought in any of those exhibitions of brute force or instinctive cunning which varied or enlivened the weariness monotony of some simple life. Still less were they conceived in the strain and stress of some wild excitement, or born in the face of urgent or unforeseen necessity. No brandished war club or protecting shield, no bitter struggles for some coveted prize, none of the demands of a purely animal existence could have furnished the impetus to cerebral special-

ization or have fed and fostered it once it had arisen.

The beginning specialization of one side of the brain, it does not matter which side, revealed itself in the preference of one hand, rather than two, for finer and more studied movements. The secret of this superiority of one side of the brain and the associated condition of handedness on the opposite side, is to be found, we believe, in the instrumentalities at the disposal of the brain for the working out of its purposes, and in the nature of the work done. When, after a long and varied experience, the accumulated products of countless mental processes should at last break through their barriers, seeking new methods of expression, and when, at last, the brain should really find something to do, it was natural and inevitable that the hands should respond to that call.

The beginnings must have been exceedingly simple, but at the same time they were equally difficult. Those first feeble, all but futile, attempts at creative activity must have taxed to the utmost all the resources of that little mind. Erratic, childish efforts, little more; play perhaps, also, rather than work; and in those early formative times, some material advantage might have been represented by an extended childhood and a long period of bodily immaturity unknown in lower forms. Characteristic of these early efforts was the purpose behind them, some preconceived notion of something to be gained, some idea, however vague, of the methods which might be employed to obtain the desired result. They were little things, for their limit was set by the caliber of the brain; their accomplishment called for no display of strength and endurance, but only for a modicum of skill and patience. The very nature of this new employment was doubtless such that in most cases the two hands would be allotted quite different tasks, but varying all the way from equally divided labor for both hands to total inactivity of one. As a rule one hand would be more specifically charged with the guidance and responsibility for the work to be accomplished; while the opposite hand, indispensable, to be sure, but lacking something in assurance and initiative, profiting always, however, by the experience and virtues of its more favored fellow, would aid as best it could, ancillary, though still invaluable.

The character of these first activities and the resultant division of labor which culminated in handedness were dictated by the brain. In its search for expression it would naturally turn to the things about it, little, simple things, which both brain and hand could grasp and hold. But although there were two strong and eager hands, ready and waiting to lay hold of anything, although the flesh was willing, the spirit was weak. It was easy enough to control two or even four limbs, in fact, to look after the entire body, where it was merely a question of the exercise of those older, inherited, animal activities which served a very different purpose; but to reach out into a new world of thought and action was a very different matter. Where, in the one case, the whole intricate mechanism of the body required but very little formal or conscious oversight, fashioned and perfected, as it had been, through millennia of unvarying routine, in the other, the effective use of even one hand alone, for the new and unprecedented procedures devised by the brain, would sorely try the new-found powers of even the best of these early brains.

One hand was enough—and often more than enough. The first simple, half-unconscious problems were solved largely through the predominant use of one hand or arm. Attacked and solved in this manner, we think, not only because the character of the work demanded or permitted unequal and different services from the hands, but rather because the brain could not give equal

and adequate oversight to both hands at once. It was by no means easy to fix the weak and wandering attention on the task in mind. To determine and carry out the necessary movements, even for one hand and in the crudest manner, was equally difficult and fraught with many failures. Only at the cost of ceaseless efforts was it possible to hold down the wavering attention, only by constant practice did the brain acquire control of itself and thereby mastery of the hand.

It was as if nature had come to the parting of the ways. Future advances in organization and efficiency were to be bought, in part, at the price of specialization. A body of fair size and considerable strength had been evolved; in its structure, proportions and equipment it was unique; as a motor mechanism, as a means of developing power in a wide variety of convenient and available forms, as a simple machine, there was little chance for improvement. Further progress could be hoped for only in the utilization of this power for newer and higher purposes. This entailed no material change, either in the source of that power or in its outward manifestations; but it did demand a very definite enhancement of the functional capacity of the brain and further refinements in its methods of operation. It was not so much a question of new movements of the hands and arms or even of new and novel combinations of old movements as it was a question of cerebral activity which could attain to, and be sustained at, a sufficiently high level to form some conception of the material possibilities implied in those intricate movements, and at the same time imbued with sufficient energy and initiative to follow the feeble light of inspiration wherever it might lead.

With a symmetrical brain presiding over a symmetrical body, there arose the choice of attempting to secure further advancement, either by adhering to a time-honored conservatism and respect for essential symmetry, or by resorting to concentration of effort and the placing of the bulk of the burden on one side of the brain and in one hand. In the natural course of events, abundant opportunity would have been afforded to try out the former method, but the latter was destined to supersede it in the greater promise it offered of fruitful and more immediate results. But as brain has always outweighed brawn—for the race was not always to the swift—so in turn parts of that brain were to outweigh others, one side was to lead the other, in the establishment of a newer and a higher order of achievement.

In the use of one hand the nervous impulses necessary for its control undergo their final elaboration in the opposite side of the brain, and from this side also make their final exit. The predominant and preferential use of one hand, the choice of one alone for more refined operations, the successful performance of which requires special care and studied coordination, are but the outward signs of a nervous activity equally refined and highly coordinated, having its seat in the opposite side of the brain. For the time being that particular side of the brain is more intensely active, and, therefore, for the moment, of greater functional importance, since it represents the last important link in the subtle nexus of brain and hand, of thought and action. Regardless of the various channels through which information may be poured into the brain, regardless, also, of the sources or location of those mental processes which are to find their ultimate expression in manual activity, it is evident that, at some stage and in some form, there must emerge on one side of the brain the materials necessary for the formulation of those final orders, the execution of which is to be intrusted to the opposite hand. The raw materials with which the mind must work may be stored in many places, on both sides of

the brain, its subsequent elaboration and preparation for use may likewise involve wide-spread participation by the higher centers; but if the end results are to manifest themselves in special activity of one hand, then one side of the brain must assume an executive rôle, issue the necessary instructions and accept all the responsibility for their proper performance.

The more one hand became the chief and acknowledged agency in the accomplishment of any purpose, profiting in skill and confidence through constant practice and repetition, the more did that side of the brain in which the control of that hand was vested, enlarge its ascendancy over the other side and further refine and perfect its own intricate processes. The slowly rising stream of purposeful endeavor, flowing outward from brain to hand in ever-increasing complexity and abundance, would draw after it, little by little, the scattered sources of its own supply and tend to focus and concentrate on the same side of the brain not only the final stages of volitional expression, but more and more of the preliminary elements and tributary factors. The resultant specialization, or functional superiority, of one side of the brain, the tendency of associated functions to cluster around some common point, is one of the economies of nature and quite in keeping with some of the most fundamental phases of nervous activity. In this particular case, the special use of one hand and arm, or rather the special quality or capacity of their controlling cortical centers, has furnished the adequate stimulus for other and even higher centers to unfold and develop most conspicuously on the same side. The specialization of the brain for adequate motor control would be more efficient and effective the farther it could reach into the sources which fed and determined that control. Borrowing a figure from political phraseology, and stretching it a little, perhaps, one might say that the executive side of the brain had found it of advantage to appropriate some of the legislative, if not also some of the judicial, functions, which, like the executive, were once equally and evenly distributed. The more definite this specialization of the brain became, the more varied and precise would be its manifestations in the activities of the hands, and both would redound in increasing measure to the profit and progress of their possessor.

But it must not be supposed that the less favored hand would suffer from this apparent slighting. The result has been not a good hand and a poor one, but a good hand and a better one. Not only this, but with increasing mental capacity, either hand is placed in a better position to profit directly by the enhanced skill and assurance of the other, the gain is not manual and local so much as it is mental and general. Nevertheless, there was a parting of the ways, a choice was presented; some division of labor for brain and hand was the apparent answer.

It has been repeatedly noted that man's first activities must have concerned themselves with little things. His eyes were sharp and his hands and arms were strong and supple, but his brain was just beginning to grasp the significance of the things which his eyes and hands had seen and felt for ages. Out of the wealth of sense impressions, present or remembered, he could only evolve a single, feeble thread of thought, only with difficulty and after many trials could he preserve its continuity and succeed in guiding it through new and untried paths into appropriate action. Though fed from various sources, his train of thought was single and unique, but frail and tenuous as well; like the vast majority of all those who have followed him, he thought, and could think, of but one thing at a time, his ideas were essentially successive and in some sequence, not contemporary or parallel. Much of that thinking, more-

over, was most inextricably bound up with the nervous mechanism in immediate control of the hand which was to translate that thinking into action. Hand and brain were working together, each serving and aiding the other, in constant and reciprocal control and guidance.

All things considered, the peculiarities and limitations of the mind and the bilateral character of its structural basis, the corresponding bilateral character of the means provided for its expression and the exceedingly intimate relations between brain and hand; each and all favored the development of a unilaterality, as contrasted with an ambilaterality, primarily of the brain but later involving other parts, favored, in a word, that specialization which has long gone under the name of handedness.

In view of what has been said, handedness was not the product of brute strength, nor was it born of mental tumult and excitement; its essential nature would stamp it as the child of quiet contemplation, for peace hath her victories no less than war. We might, perhaps, picture some uncouth, slouching form, seated at the foot of some great tree or crouched in the cool shelter of some rocky den. Perchance, we should have found him far afield, bent on some special mission, or guided in his ramblings more by native curiosity than preconceived intent, at peace with himself and the world. Somehow his hands would find employment. It may have been only a passing childish interest, something held for a moment in the hands, then cast aside, prompted, perhaps, by some haunting recollection of what was or might have been. It may have been mere aimless play, something to pass the time away, but in the doing some stray sparks may have kindled the light of inspiration or some unforeseen result may have struck the astonished workman with the possibilities of his craft and spurred him on to new endeavors.

The exact nature of man's first activities we shall never know, nor does it indeed concern us; important only was the overshadowing activity and importance of one hand. It does not seem necessary to suppose that the first fruits of his hands should serve some useful purpose, either by design or accident; some real or fancied need may never have occurred to him. His first attempts may have yielded little beyond the joy and satisfaction of creation; beauty may be older than utility, the artist may antedate the artisan. He may well have worked alone at first, half-conscious of his own superiority as the chosen vessel unto better things, patiently plying his little trade, while his less gifted brothers looked on in blank amazement or turned again to their fleshpots. He may have used the right hand or the left, we can not say, he may well have tried them both, learning only by experience which was the better hand. But as time went on, as generation followed generation, it became more and more apparent that a definite choice of hands was being made and that henceforth what we now call the right hand was to wield almost undisputed sway. There were always those who preferred the other side, but they stood out only by reason of that contrast, as there were also a few with naught to distinguish one side from the other.

The reasons for the initial, individual selection of one hand rather than the other, as the more suitable instrument, are hidden from us as completely as are the factors which ultimately brought about the dominance of the right hand as a final, racial character. Even from our present *ex cathedra* position, no peculiar virtues or advantages of the right hand or the left brain are at all apparent. Yet these are the riddles propounded by the classical question of right- and left-handedness, interesting, to be sure, but lacking any deeper importance, and the prospects

for their solution appear so dubious that we are quite willing to leave the quest to others.

If the beginnings were feeble, they were none the less prophetic. Countless centuries had faded into the endless past before the stage was even set for man's appearance. If, at last, his advancement became more rapid and more certain, it was still slow and arduous, for in the sweat of his face should he eat bread. Within his shaggy head, behind that flattened brow, there dimly stirred the most portentous forces. But no Pallas ever sprang from such a head; the ascent of Parnassus was yet a long way off. Time, and a goodly measure of it, was necessary to consolidate the ground already won, and to shake off the many stragglers, too blinded by their senses to see or heed the inner light. Time only could pick up and save the tiny increments, winnow some small but steady gains, and weld them through the passing years into better and more permanent form. Slowly but surely he plodded forward, not knowing whither he went. Many there were who could only marvel dumbly as he passed them by, lacking the brain which led him onward, blind to the light he followed. Little by little it must have dawned upon him that he was not like the beasts of the field, but that he stood in certain contrast to all things else, superior and aloof, in the world but not of it. Nor could he have escaped the immense importance of his hands, willing servants in a hundred different ways. One hand was better than the other, and he let it go at that; content to recognize the better of two things and call it right.

He could not have known how close he stood to the headwaters of all human achievement; he could not have known that history was in the making and that his progeny should be as the sands of the sea. He could not have dreamed that he was daily forging the material and intellectual weapons and accoutrement with which his children and his children's children for a thousand generations should gird themselves for mastery of the world, and which, all too often, they would turn against each other. His wildest phantasms could have given him no inkling of what the future might have in store, the heaped-up tribute brought by human hands. Still less was it possible to fathom the inner springs of action, the feelings which darkly stirred somewhere within him, the driving forces of which he was but dimly aware.

But primeval man, with all his natural frailties, could soon have recognized the essential nature and the sources of his own supremacy. His daily life would have taught him the value of his hands and what might be expected of them; as it would have brought about a fuller realization of the extent to which he could mold and fashion the things about him, and extend and multiply his resources. He would have learned that he could not put his trust in sheer weight of strength, nor hope to accomplish the desired results merely by the blind use of force. He would have realized ever more clearly that back of his hands and arms, somewhere within him, there was something which far outweighed his mightiest foes, something upon which he could lean in time of need, something which he could pit against his most perplexing problems. Slowly the accumulations of long experience would assume more definite form and many a nameless Nestor could teach his growing sons the young tradition;

> It is not strength, but art obtains the prize,
> And to be swift is less than to be wise.

As the hands had long been idle, awaiting the development of the brain which could employ them, so the voice had been dumb and all but silent. The hands were ready when the brain found something to do, and likewise the mechanism for speech was ready when the brain found something to say.

The nervous control of the muscles concerned with speech is bilateral, the muscles on one side being connected with the opposite side of the brain. They are quite as ancient as any of the muscles of the limbs and in their primary functions, in feeding and breathing, their original nervous control is still unaltered. In their newer rôle, however, in relation to speech, but only for this purpose, they are presided over by a highly developed nervous mechanism, the speech center, which has its seat on that side of the brain which controls the favored hand. This unilateral control of bilaterally disposed and bilaterally acting muscles is most significant. It is part and parcel of that cerebral specialization which reveals itself most conspicuously in handedness. Its location on the left side, in the majority of cases, is to be looked upon as secondary to the functional superiority of this side of the brain, and that in a twofold sense. In the first place, this is the side of the brain most directly concerned with those peculiar activities, manual manipulations involving the higher mental faculties, the very nature of which would create a need for language and favor its development. In the second place, and probably of greater importance, was the rôle of the favored hand and arm, in supplementing and more sharply defining the earliest linguistic efforts. The fact that the speech center, so-called, is single and unilateral rather than double is an even more striking example of late functional specialization than is the predominant use of one upper extremity. In the case of the former, the peripheral, active organ is single and a unit in its activity, although made up of two symmetrical halves, belonging to either side of the body. In the latter case the organs are wholly separate, paired and entirely independent of each other. The original control of one limb is from one, the opposite side, of the brain; the original control of the muscles eventually used in speech, is, on the contrary, from both sides of the brain. If we are right in supposing that the brain sought and found expression in action before it did in speech, then we can hardly escape the conclusion that signs and movements were an early and persistent characteristic of primitive language. The use of them to-day is one of our oldest habits, as it is also the best evidence of their general utility and effectiveness. The development of spoken language must have provided a most powerful stimulus to all the intellectual faculties, quickening and refining the mental processes, and making for speed and economy.

Although there was doubtless a long period during which handedness was being developed, before the choice was finally settled on one side of the brain or the opposite hand, in the case of speech, as just noted, that period of uncertainty may have been much shorter, since the ground had been prepared, to some extent, in advance, and the essential principles had already been laid down. Henceforth the dominance of one side of the brain in both word and deed was assured, cerebral specialization had been established.

But there is another side to the picture which we have drawn, a much more somber side and marred by many shadows. We may not forget the soil from which man sprung, nor pass by his long infancy cradled in the dust of the ground. However high he may have reared his head against the sky, whatever crown he may yet place upon his own brow, he was deeply rooted in the earth beneath, his feet are still of clay. A child of sense and born of the flesh, his achievements, unique and remarkable though they were, could rise no higher than their source. With all his skill and insight, he lived in a material world, worked with material things, for material ends, animated by some passing whim or driven by physical desires. His various mental processes, even the highest of them, were at first little more than

transfigured bodily activity, his thinking was primarily a doing, and his motives still bore the deep imprint of their lowly origin. He was self-centered and naturally selfish, for the old Adam still hung over him with all but crushing force.

He had served a long and weary apprenticeship in training his brain and hands and lips to do his bidding, but a harder task awaited him in the clarifying and refining of the motives which were to actuate him. He was splendidly equipped, but that equipment might serve any purpose, either good or bad; power was his and the ability to accomplish things, but that power and ability had to be directed into proper channels; he had yet to learn how to use the forces at his command for the greatest good of all, he had yet to realize that might does not make right.

We can not wonder, then, if all his proud attainments and all his vaunted skill and ingenuity brought with them no immediate guarantee of commensurate uprightness and probity, no visible surety for those gentler qualities which make up the milk of human kindness. It could not have been otherwise. He was animal and selfish, before he was human and unselfish; but he also had been an animal immeasurably longer than he had been a man. His brain and his hands were his own, and their primary function was to serve him; acutely sensitive to his own wants, he was naturally slow to recognize the rights of others. If the conquest of crass material forces had been so slow and costly, how much longer before they could serve the common good in peace and equity. 'Tis hardly strange that the animal within should break through the thin veneer of human culture; that, drunk with new-found power and the prey to low desires, man should tear down his own temples and lay waste his own shrines, let loose the lightnings round his head or follow after strange gods to his own undoing. It was a hard school, but he had much to learn. Too often has he mistaken liberty for license and drunk the bitter lees of retribution. Too often has he called down upon his head the fierce denunciation of his fellow men, Swift's stinging satire in the tale of the Houyhnhnms. Too well and all too often has he merited the sulphurous sarcasm of Mephistopheles, who, in recounting for the Creator his impressions of the new world, of the new man and of his boasted power, could only say:

Er nennt's Vernunft und braucht's allein,
Nur tierischer als jedes Tier zu sein.

The little leaven, which many times seemed hopelessly submerged, was hidden in a vast amount of meal; it was yet a long time until Shiloh came.

The age-old struggle for supremacy, between brawn and brain, was fought out on many fields, with many diverse weapons. Its apogee is marked by that cerebral specialization whose outward sign we know as handedness. Language, and perhaps other intellectual attributes, likewise enjoy its benefits. It was like the contest between Ajax and Ulysses for the divine armor of Achilles. But again the outcome was never in doubt; the towering, insolent, bloodthirty son of Telamon was but a mean match for the wise and cunning king of rocky Ithaca.

Not by bulky size,
Or shoulder's breadth, the perfect man is known;
But wisdom gives chief power in all the world.

BOTANIZING ON BARRO COLORADO ISLAND, PANAMA

By Professor L. A. KENOYER

WESTERN STATE TEACHERS COLLEGE, KALAMAZOO, MICH.

Our national engineering achievement in Panama has opened to the traveler a waterway with constantly shifting scenes of luxuriant tropical life. At about the middle of this enchanting fifty-mile journey through the canal he may observe on a promontory jutting against the waterway the following sign:

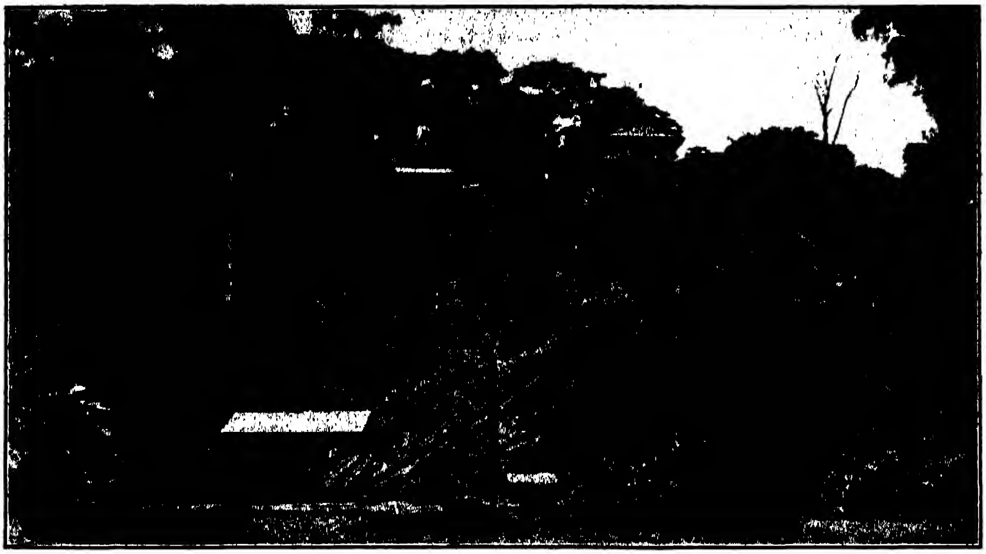
INSTITUTE FOR RESEARCH IN TROPICAL AMERICA
BARRO COLORADO ISLAND BIOLOGICAL LABORATORY
This island was set aside April 17, 1923, by the Governor of the Panama Canal as a natural park and biological preserve
TRESPASSING PROHIBITED

Barro Colorado Island, with its six square miles of tropical forest, is the largest island in Gatun Lake, the artificial 164 square mile sheet of water which constitutes the central part of the canal. The island is about eleven miles from Gatun Dam, which was built across the valley of the Chagres River to form the lake, and about the same distance from the equally famous Culebra Cut, where one hundred ten million cubic feet of rock and earth were removed to bring about the realization of the motto expressed on the official seal of the Canal Zone, "The land divided; the world united." Lying but nine degrees north of the equator, the island affords a fair sample of the biological wealth of the vast American tropical region. In the commodious laboratory erected by the National Research Council and several cooperating educational institutions, one can enjoy the comforts of civilization while investigating the primitive jungle of the tropics.

There has been much written about the birds, mammals and insects of this area.[1] The forest which furnishes the setting for this vast array of animate activity is worthy of study. It is classified by botanists as a rain forest. The vegetation is not so fully adapted to humid conditions, however, as is that of the Amazon Valley. It has some of the characteristics of that other tropical forest type, the monsoon forest, which attains typical development in British India and other regions with an annual climate fluctuating from extreme dampness to extreme dryness. The island receives about 115 inches of rainfall annually, only ten to fifteen of which fall during the first five months. The dry season is far less prolonged and less severe than in the typical monsoon region, yet it is distinct enough to cause a definitely periodic behavior, with a well-marked leafless period in a number of the tree species. Oceanic conditions prevent extreme temperatures, the range being from 69 to 89 degrees Fahrenheit.

About half of the island, the portion most remote from the laboratory and canal, is splendid primeval forest. The half nearest the laboratory and canal has not, except in ravines, any trees of more than about a foot in diameter, hence presumably it was in cultivation up to about fifty years ago. A rusty dump-cart lying inverted along one of the trails of this portion recalls the days when the French pioneers tried to carry out the century-old vision of a canal across the isthmus. One wonders how it

[1] See George Shiras 3d, "Nature's Transformation at Panama." *National Geographic Magazine*, August, 1915; and Frank M. Chapman, "Who Treads our Trails?" *National Geographic Magazine*, September, 1927.



LABORATORY OF THE INSTITUTE FOR RESEARCH IN TROPICAL AMERICA

PERCHED ON A HILL OVERLOOKING THE BAY AND THE FORESTED VALLEYS ON EITHER SIDE IS THIS NEAT AND COMFORTABLE LABORATORY BUILDING. FROM THE LABORATORY NO LESS THAN SIXTY OF THE NATIVE TREE AND SHRUB SPECIES MAY BE OBSERVED.

A VILLAGE IN RURAL PANAMA

UP THE CHAGRES RIVER, ABOUT TWO MILES BEYOND THE BORDERS OF THE CANAL ZONE, THE QUAINT LITTLE VILLAGE OF SANTA ROSA PURSUES ITS PEACEFUL RUSTIC WAYS. CANE STALKS FROM NEAR-BY MARSHES PROVIDE THE WALLS, PALM LEAVES THE THATCHED ROOFS. THE ONLY PLACE OF BUSINESS IN THE VILLAGE IS A SALOON AND GENERAL STORE WITH A CHINESE PROPRIETOR.

DISPLAY OF TROPICAL FOLIAGE SEEN FROM THE RESEARCH LABORATORY
ABOVE IS THE COROZO PALM, A SINGLE LEAF OF WHICH HAS A LENGTH OF FORTY FEET. BELOW, AT LEFT, A RELATIVE OF BRAZIL-NUT; IN CENTER, THE BANANA; AT RIGHT, THE PAPAYA.

got to this five hundred-foot elevation. Probably the peasants who cultivated the area made some use of it. But today the area in which it lies is being rapidly reclaimed by the jungle. The French failure in Panama followed their success in Suez. But we can scarcely imagine two regions affording a more striking contrast than do Suez and Panama. One of them is a barren sandy desert, the other a luxuriant humid forest. We can not, therefore, wonder that De Lesseps and his colaborers, having conquered one situation, were unable to cope with the very different conditions in the other.

Barro Colorado, signifying in Spanish "red clay," was the name of this region before human handiwork made it an island. Its subsoil is of a vivid red and is underlain by reddish sandstones and conglomerates. History tells us that the courageous but unprincipled British pirate, Henry Morgan, as he marched across the isthmus to raid Panama City, was repulsed for a time by a band of Panamanians stationed at Barro Colorado, but that the resistance finally broke down and permitted the raiders to carry out their dastardly ambition.

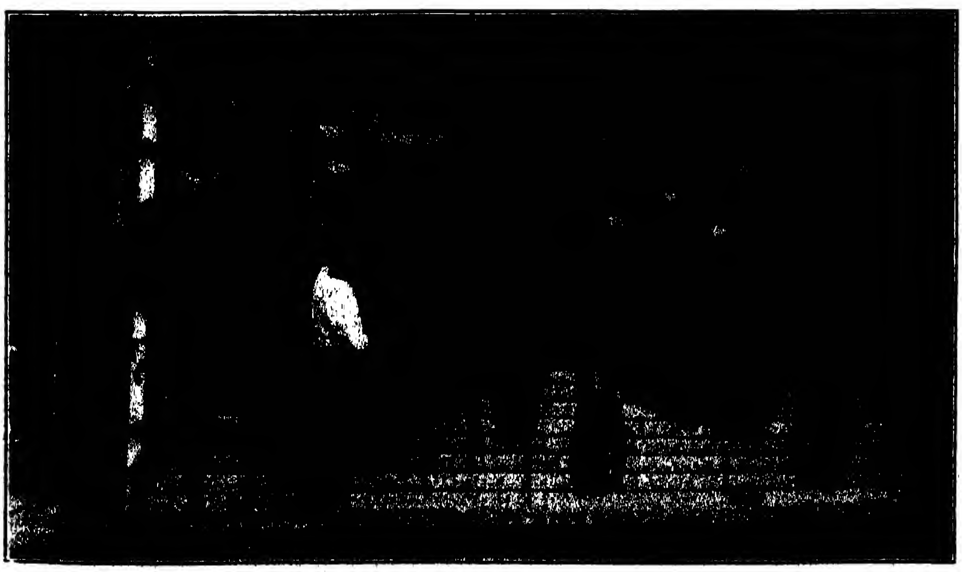
The species of seed-plants and ferns thus far listed for the island number about 725. Much of the area has not yet been thoroughly explored, hence the whole number probably exceeds one thousand. This is approximately twice the number for an average similar area in the temperate zone. Moreover, the relative showing of the different growth forms, termed by botanists the plant spectrum, is quite different. Of the eleven hundred plant species of a typical Michigan county, about 16 per cent. are trees and shrubs, while of the Barro Colorado species about 52 per cent. are trees and shrubs. Plant families that are mainly herbaceous in our flora—such families as the buckwheat, the spurge, the meadow beauty, the morning glory, the nightshade, the madder—are prevailingly shrubs and trees in the tropics.

In consequence of this great diversity of woody plants, one can not so easily pick out dominant trees as in our

own region. In the latter we speak of beech-maple forests, oak-hickory forests, tamarack bogs, pine dunes and the like, but in Panama we should probably have to list at least twenty-five species among our dominants. From a point of vantage, such as the laboratory building, one can count at least sixty species of trees and large shrubs. Rarely do more than two or three trees of a species appear at one time to the observer on the forest trail.

Another outstanding fact is the great size of some of the trees. The abundance of smaller as well as larger types is such that the large trees are not particularly crowded. On a walk of a kilometer (one half mile) through the virgin forest, the writer counted 150 trees having a diameter of two feet or over. One might do better in almost any of the few remaining primeval forests in the United States. But the big trees—some of them at least—are exceedingly big. A specimen of "spiny cedar" (*Bombacopsis Fendleri*) has a basal circumference, around the outside of the huge buttresses, of about 190 feet. Its top rises like a huge dome above the forest roof and spreads to a diameter of two hundred feet. At the foot of such a giant a mere man dwindles into insignificance. The flat triangular buttresses which brace the base on all sides sometimes meet at the outer ends in such a way as to form fair-sized rooms with high perpendicular walls. One of these rooms is dark enough to provide a comfortable home for bats.

In height the trees are not equal to those of the conifer forests of our Pacific states. The tallest are about 150 feet high, the average of the forest canopy probably not exceeding one hundred feet. It would seem that Bombacopsis and the few other species of tall-growing trees have so much competition in early life with less tall-growing forms that relatively few of them survive to become tall trees. Then, as they out-

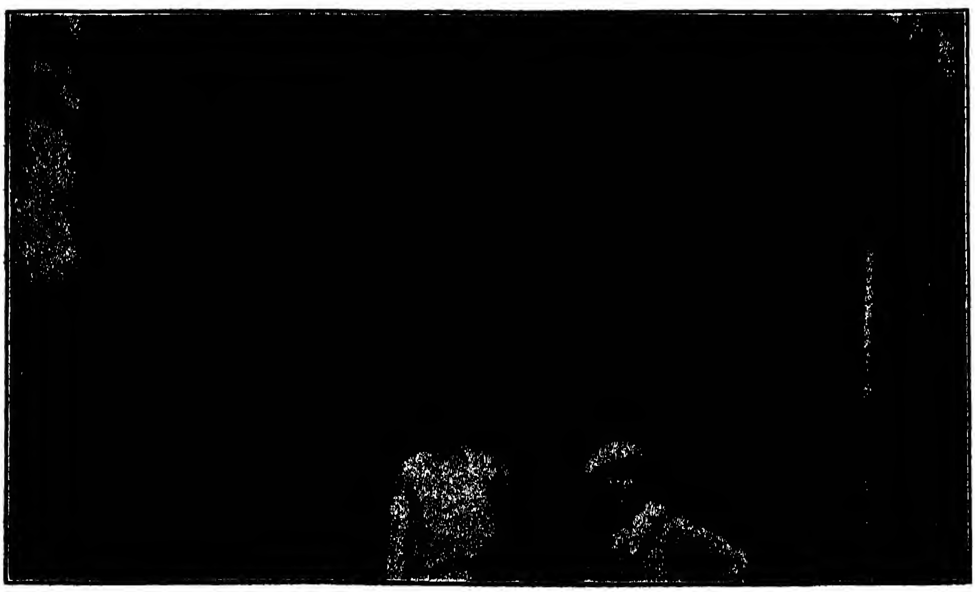


SOME BIG LEAVES OF THE RAIN FOREST

LEAVES OF TROPICAL PLANTS ARE OFTEN MUCH LARGER THAN THOSE OF TEMPERATE SPECIES. THE LARGEST ARE THOSE OF A PALM (EXTENDING DIAGONALLY ACROSS THE VIEW), AND OF A TREE FERN (UPRIGHT, AT LEFT). THE LARGEST UNDIVIDED LEAVES ARE THOSE OF THE BANANA (AT RIGHT) AND SOME OF ITS WILD RELATIVES (NEAR CENTER).

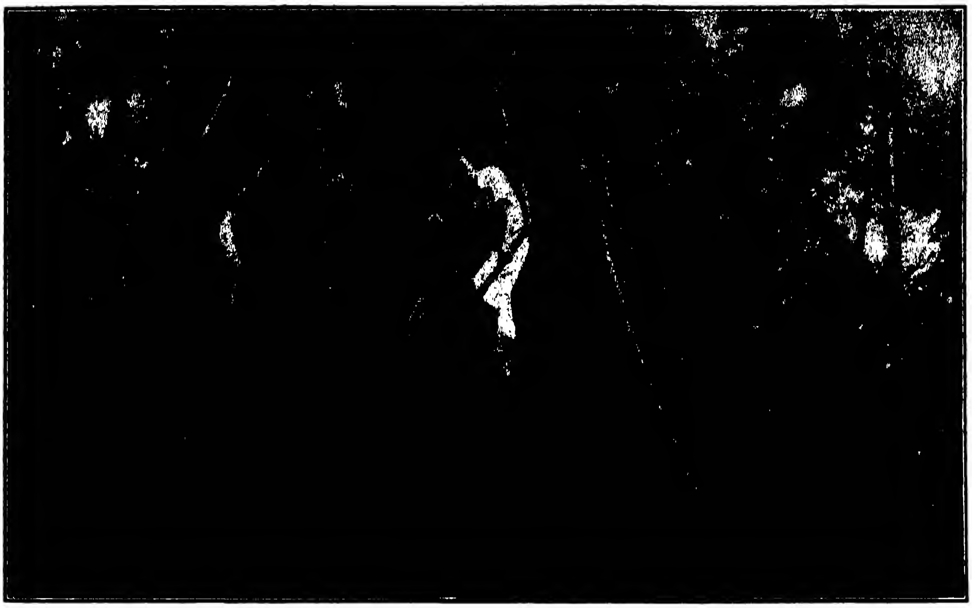
BIGGEST TREE OF THE ISLAND JUNGLE

THIS MAGNIFICENT SPECIMEN OF "SPINY CEDAR" (*Bombacopsis Fendleri*) HAS A BASAL CIRCUMFERENCE OF 190 FEET (INCLUDING THE HUGE BUTTRESSES), A HEIGHT OF ABOUT 150 FEET AND A TOP SPREADING IN A HUGE DOME WITH A DIAMETER OF 200 FEET. THE WALL-LIKE BUTTRESSES AROUND THE BASE INCLUDE AREAS SOME OF WHICH WOULD MAKE FAIR-SIZED LIVING ROOMS.



NEAR VIEW OF THE BIGGEST TREE

TWO BUTTRESSES MEETING IN CENTER OF THE VIEW FORM A ROOM SO DARK THAT IT IS OCCUPIED BY BATS.



BIGGEST TREE TEN FEET ABOVE GROUND

NOTICE THE NATURE OF THE HUGE PLANK BUTTRESSES, THE PROFUSION OF LIANAS WHICH ENABLE ONE TO CLIMB WELL UP THE TRUNK, AND THE CHARACTERISTIC HORIZONTAL GROWTH LINES ON TRUNK AND BUTTRESSES. THE LIGHT PATCHES ARE LICHENS. THE SPREADING BRANCHES CONSTITUTE A VERITABLE BOTANICAL GARDEN WITH A WEALTH OF FERNS, AROIDS, ORCHIDS, PEPEROMIAS, ETC.

grow their neighbors, the tendency is to spread outward rather than to continue upward.

Many of the other trees resemble Bombacopsis in the development of basal buttresses. Winds, which are frequently severe, will not easily overturn a tree that is fortified in this manner. A similar strengthening device is the prop root system, which is found about the base of trees of a number of species, but which is most beautifully developed in the stilt palm, a tall graceful tree abundant in the forest.

A striking feature of the tropical forest is the great size of many of the leaves. The largest is the pinnate leaf of the Corozo Palm, measuring forty feet from base to tip. The banana and several of its wild relatives possess very large undivided leaves.

At various times during the year different trees are ablaze with a wealth of colored blossoms. The dry season is preeminently blossom season. At this time there are few rains to wash away the pollen, and the sparseness or absence of foliage on some of the trees permits greater freedom in pollen distribution. But even during the rainy months bright patches appear here and there in the forest, as various species display the purple, gold or red of their flowers. The effect is heightened by the gay plumage of parrots, toucans and other brightly colored birds and the intense blue of the Morpho butterfly, while the call of the wild turkey and the cry of the howler monkey make vivid the realization that one is indeed in the abode of life.

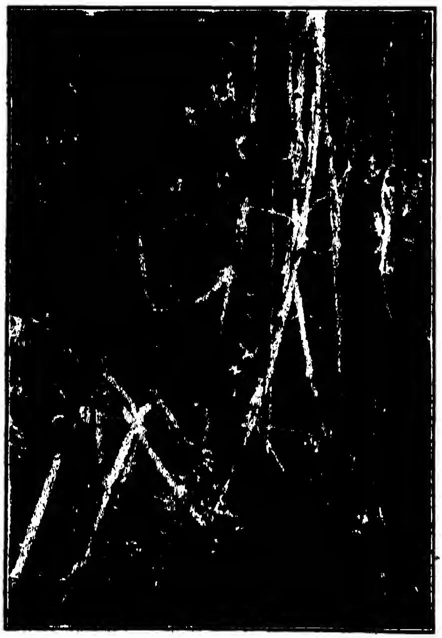
The rain forest is noted for climbing plants. Great festoons of stems, perhaps ten or more species on the same tree, hang down from the branches or form tangles along the trunks. To

secure light is the great problem in such a forest and these plants get their foliage to light without the expense of constructing a self-supporting trunk. Many of these climbers retain life so tenaciously that, if cut off, the upper part sends down new roots and re-establishes its connection with the ground. Climbers of the twining type often strangle the tree that supports them by constricting its food-carrying tissues.

Taking similar advantage of the better illumination afforded by a position above ground is a noteworthy group of hemiepiphytes (half-way epiphytes, or living upon another plant in early life only). These include several species of strangling fig and some members of other families. These plants generally begin life on a branch high in the supporting tree. Roots extend down along the trunk of the supporter to the ground. These roots branch out and rejoin one another in such a fashion as to form a network that may completely enmesh the supporting trunk. The mesh may finally close up, leaving only the fig tree visible, while the supporting one is wholly imbedded within it. Strangled till growth in diameter is no longer possible, our original tree may die, leaving only the strangler.

FRENCH DUMP CART IN SECOND GROWTH FOREST

MUTE EVIDENCE OF A GOAL PURSUED THROUGH SEVERAL DECADES AND FINALLY OVERWHELMED BY THE DISEASE-BEARING MOSQUITO. THIS SITE, FOUR HUNDRED FEET ABOVE THE LAKE, MAY HAVE BEEN THE HOME OF A BANANA-GROWER WHO MADE SOME USE OF THE CART AFTER THE FRENCH ENGINEERS HAD ABANDONED IT. THIS PART OF THE ISLAND IS NOW COVERED WITH A DENSE TANGLE OF SHRUBS AND VINES AND MEDIUM-SIZED TREES.



THE BIG TREES OF THE FOREST ARE FESTOONED WITH LIANAS

CLIMBING PLANTS OF MANY SORTS TAKE ADVANTAGE OF THE CHANCE FOR LIGHT AFFORDED BY THE SPREADING TOPS OF THE BIG TREES. SOME OF THE STEMS ARE NOT IN CONTACT WITH THE TREE-TRUNK, SUGGESTING THAT THEY CLIMBED UPON OTHER TREES WHICH HAVE SINCE DISAPPEARED. THE SLENDER CORDS ARE ROOTS OF EPIPHYTIC AROIDS EXTENDING DOWNWARD TO CONNECT THE PLANT WITH THE SOIL.

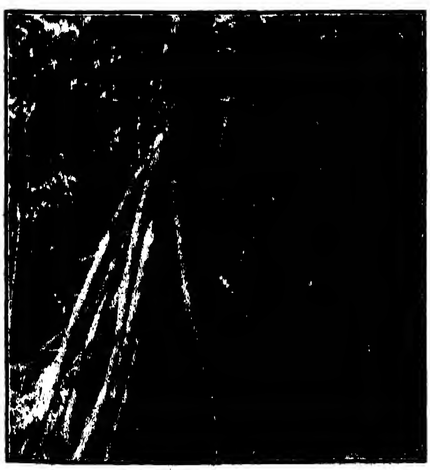
An epiphyte ("upon plant") is a plant that uses another merely as a support, not as a source of nourishment. Epiphytes are exceedingly numerous in the rain forest. The branches of a big tree form a veritable botanical garden, occupied by ferns, aroids, orchids, cistern-plants, cacti and various other plants. As the writer walked along the

trail with a vague longing for the climbing ability of his brethren of the monkey tribe so that he might explore these gardens, he found a tall tree which, recently broken by the wind, was lying across the path. On it were found ten kinds of epiphytes and eight kinds of climbers. A violent attack ensued as he proceeded to gather epiphytes from one conspicuous clump which had been high in the tree top, for a colony of stinging ants had taken up its abode in the matted roots of the plants.

Aroids (relatives of our Jack-in-the-pulpit) are very numerous and seem to prefer the tree-top situations, both as climbers and as epiphytes. Some have huge leaves and loom up conspicuously on the trees. One frequently sees ferns of the bird's-nest type, *i.e.*, with the broad leaves arranged around their place of attachment in such a fashion as to form a basket or nest. This collects humus and helps to retain water for the plant. The cistern-plants (bromelias or relatives of the pineapple) have a more pronounced receptacle which catches the rain-water and retains it until it can be absorbed by the plant. Epiphytic orchids are numerous. These plants have long attracted the attention of the collector because of their peculiar flower structure, very highly specialized for the secural of cross-pollination by insects. One common stump-inhabiting orchid has concealed within its large yellow bonnet-like flower a prominent trigger. The touch of the insect against the trigger causes the pollen mass to be dislodged and thrown with force toward the opening of the flower. Attached to this mass is a sticky gland which adheres to the insect. The pollen mass is thereby carried to the next flower visited and thrust against the stigma. Orchids have air roots pressed against the limb on which they grow or hanging freely in the air. The outside layer of the root consists of porous cells that take up water like blotting paper.

HOW TWINERS AFFECT TREES

THE CONSTRICTION BY A TWINER OF THE FOOD TUBES OF THE TREE ON THE RIGHT HAS CAUSED THE FOOD TO BE UTILIZED IN EXCESSIVE GROWTH JUST ABOVE THE COILS, GIVING THE TRUNK A CORRUGATED APPEARANCE. THE TWINER ITSELF HAS DIED AND DECAYED, DEATH BEING PROBABLY DUE TO STRETCHING BY THE ENLARGEMENT OF THE TREE. THE GRACEFUL STEM OF A PALM IS SHOWN ON THE LEFT.



SUPPORTING ROOTS OF THE STILT PALM

TWIN SPECIMENS OF THE STILT PALM (*Iriartea exorrhiza*) SHOW THE INTERESTING FASHION IN WHICH THIS TREE HAS SOLVED THE PROBLEM OF SUPPORTING ITS TALL SLENDER TRUNK. THIS IS ONE OF THE MOST ABUNDANT AND BEAUTIFUL PALMS OF THE FOREST.

Most epiphytes have a striking resistance to drought. Living as they do without a soil connection, they would not be able to endure the inevitable dry period without such resistance. In some cases, the resurrection plant type, the leaf is able to dry and to resume activities when again soaked with water. To this type belong the filmy ferns, which have such very thin delicate leaves as to appear like water-plants. In others, the leaves are thick enough to store water and waterproofed enough to prevent its loss. Certain fern and aroid leaves placed in the laboratory attic just under the corrugated iron roof, where midday temperatures become very high, remained for a month without appreciable loss of water.

AN INTERESTING PARASITE FROM BARRO COLORADO

Apodanthes Flacourtiae IS PARASITIC ON A SPECIES OF XYLOSMA. THE WHOLE PLANT IS INSIDE THE HOST WITH THE EXCEPTION OF THE LITTLE WHITE FLOWER THAT BREAKS THROUGH THE BARK. THIS PLANT BELONGS TO THE RAFFLESIA FAMILY, A GROUP HITHERTO UNREPORTED FOR CENTRAL AMERICA.

A FERN-FRINGED BANK OF THE OLD FRENCH CANAL

AN INTERESTING BIT OF THE WORK OF THE FRENCH COMPANY BRANCHES OFF THE PRESENT CANAL. HERE IT WAS PLANNED TO PLACE ONE OF THE LOCKS. THE CONTINUAL BEATING OF WAVES IN THE WAKE OF VESSELS EXPOSES THE SANDSTONE, WHICH IS HERE GRACEFULLY DROOPED WITH THE FERN, *Nephrolepis pendula*, A NEAR RELATIVE OF THE WELL-KNOWN BOSTON FERN.

One can scarcely comprehend the difficulties that beset the botanist who would identify the trees of the tropics. The nearest leaves may be one hundred feet from the ground. If they are large enough, or have striking characteristics, he may be able to recognize them by using an opera glass. But so many trees have leaves so provokingly ordinary that they are not recognizable at a distance. He then looks about for leaves that may have fallen to the ground. He picks up a leaf. The question then arises whether it came from the tree itself, from some one of the twenty sorts of plants climbing or nestling upon it, or from some one of the numerous tree species crowded around the one in question. He defers the solution for further evidence, which may not be easily secured.

Barro Colorado Island has twenty-five miles of shore-line. It is along

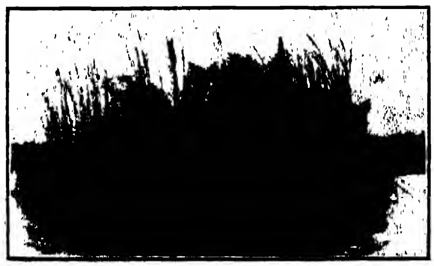
INHABITED STUMP IN GATUN LAKE

THE WRECKAGE OF TREES, DESTROYED WHEN THE WATER WAS TURNED IN BEHIND GATUN DAM, IS OFTEN COVERED WITH EPIPHYTIC PLANTS. AT THE LEFT IS AN AROID (*Anthurium rigidulum*), ON THE RIGHT IS A REMARKABLY THICK-LEAVED TREE (*Clusia* SP.). A LARGE COLONY OF WASPS SUGGESTS CAUTION ON THE PART OF THE COLLECTOR.

A TREE ALIVE AFTER THIRTEEN YEARS OF FLOODING

THIS LARGE SPECIMEN OF *Bombacopsis Fendleri* IS ONE FOURTH MILE FROM THE NEAREST SHORE. IN SPITE OF HAVING STOOD IN SIXTY FEET OF WATER SINCE THE TIME OF THE CANAL CONSTRUCTION ITS BARK HAS HEALED AT THE WATER LEVEL AND HAS SENT DOWN ROOTS ENOUGH TO KEEP ALIVE A FEW TWIGS SCATTERED OVER THE BRANCHES.

these shores that one can do the most profitable plant collecting. In mid-forest the trees are so high that the collector must be content with leaves and flowers that have fallen upon the ground. But along the shore, practically all the foliage comes down to the water's edge, where it can easily be gathered by the botanist who paddles along in an Indian log canoe and is equipped with a pruning hook on a long pole. This newly formed shore gives one an excellent opportunity for the study of the adjustment of plant life to new environments. Thousands of trees were flooded and



A MARSH ISLAND IN GATUN LAKE

ON THE SIDE OF BARRO COLORADO ISLAND, AWAY FROM THE AGITATION CAUSED BY CANAL TRAFFIC, HUNDREDS OF LITTLE ISLANDS OF MARSH GROWTH ARE DEVELOPING. MANY OF THEM STARTED ON STUMPS OF THE DROWNED TREES. THE PRINCIPAL PLANTS ARE CAT-TAIL AND MARSH FERN.

killed. Many of the plants lodged on their branches were forced to give up because of the intense sunlight and the loss of bark from the dead trees, but some of the more hardy ferns, orchids and aroids remain. A new type of vegetation, the swamp type, has invaded the area. In the more quiet waters on the side of the island away from the canal are hundreds of little islands made up of masses of cat-tail, marsh fern, arrow-head, hibiscus, sedges and other plants. Some of these islands had their origin on a stump coming up to the water surface, others on places where the soil comes

A LARGE-LEAVED AROID

Anthurium maximum IS TYPICAL OF A GROUP OF RAIN FOREST PLANTS WHICH, FORSAKING THE GROUND, PERCH WHERE LIGHT IS PLENTIFUL. USUALLY IT GROWS ON TRUNKS OR BRANCHES OF TREES, BUT THIS SPECIMEN OCCUPIES THE TOP OF A LARGE ROCK. LACKING ANY CONNECTION WITH SOIL WATER, IT MUST BE FITTED TO WITHSTAND DROUGHT, HENCE THE FOUR-FOOT LEAVES ARE SO LEATHERY AND WATERPROOFED THAT IT TAKES A MONTH OF DRYING TO MAKE ANY IMPRESSION UPON THEM. THE FRUIT CLUSTERS, TWO OF WHICH HANG FROM THE CROWN, ARE BUILT ON THE SAME PLAN AS THOSE OF JACK-IN-THE-PULPIT, SKUNK CABBAGE OR CALLA.

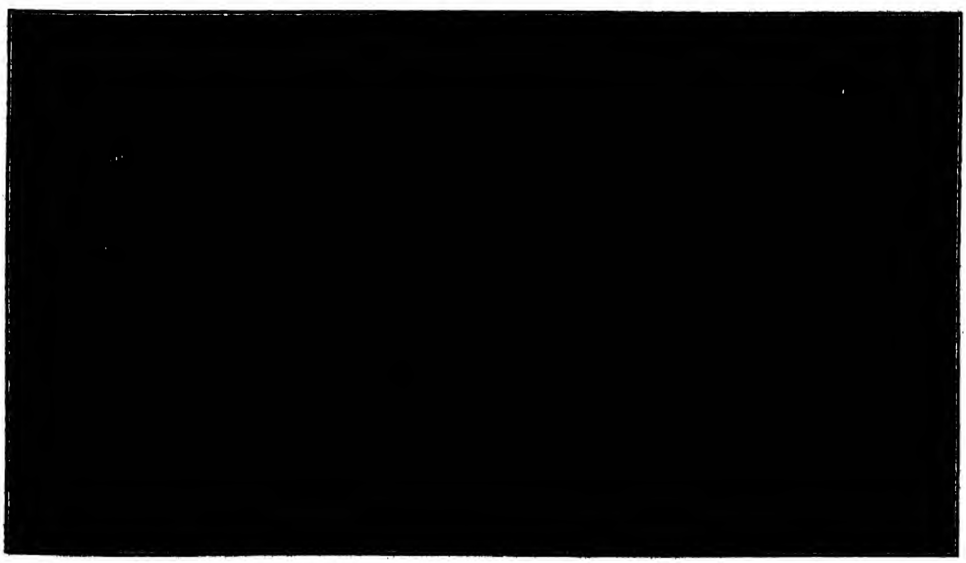
almost to the water-level. The parts of Barro Colorado next to the canal are subjected to considerable agitation of the water, for the waves generated by passing vessels strike and erode the shores. Swamp formations are almost lacking on this side, but instead there are lake bluffs with a characteristic vegetation. Trees are uprooted, the logs drifting into and filling the shallow bays.

Thorny-stemmed trees are abundant. He who reaches a hand to the nearest palm trunk to steady himself as he walks through the forest must beware, for palms of some species are bristling with thorns. Prickly ash, known only as a shrub in our temperate climate, is represented in the tropics by several large trees with broad-based spines.

Ferns attain their greatest profusion on tropical mountain-tops. Our island,

however, has nearly one hundred species, belonging to nine different families. This is a good showing for a sea-level forest. The most striking of tropical ferns are the tree-ferns. Barro Colorado has three species belonging to this family. Representatives of one species stand thirty feet high in some of the ravines.

The attention of the plant lover is always attracted by those peculiar flowering plants which lack chlorophyll, and hence secure their food by methods other than that used by the ordinary green plant. These are parasites, which get their food directly from living plants, and saprophytes, which get their food from decaying matter in the soil, usually with the aid of a fungus which occupies the root system. The former are represented in the northern United States by dodder, mistletoe and beech-drops; the latter by Indian pipe and coral-root orchid. Aside from fungi, parasites are not numerous in the moist tropical lowlands. But the writer had the privilege of finding one of great interest. In the forests of the East Indies there appears on the trailing stem of a woody climber of the grape family an enormous blossom, sometimes a meter in diameter. The remainder of this strange plant, known as Rafflesia, is entirely within the stem of its host. The Barro Colorado plant is a small member of the Rafflesia family, displaying vertical lines of delicate white waxy flowers, which burst through the bark of the small tree serving as host to the parasite. Its discovery gives us the first record for this family in Central America. As one goes through the big forest he frequently encounters a delicate little leafless plant of a pale Venetian pink, springing up singly or in pairs from the rich leaf mold. This plant gets its food much as does the Indian pipe, *i.e.*, by cooperation with a fungus, which absorbs decaying matter from the soil, delivering part of it to our delicate little saprophyte. The plant is Ophiomeris, of the Burmannia Family, and is known only on Barro Colorado, where it was discovered two years ago.



SPINY TRUNK OF THE FAN PALM

SEVERAL OF THE PALMS AND OTHER TREES OF THE FOREST ARE ARMED WITH FORMIDABLE SPINES, BUT THOSE OF *Acanthorrhiza Warscewiczii* ARE THE LONGEST AND SHARPEST.

OLDEST KNOWN TREE OF BARRO COLORADO

THIS PETRIFIED STUMP, RECENTLY UNCOVERED BY EROSION, TELLS OF A HUGE FOREST DENIZEN OF SEVERAL MILLION YEARS AGO. THE TREE WAS A METER IN DIAMETER, COMPARING VERY WELL WITH THE AVERAGE LARGE TREE OF TO-DAY. THE HOLLOW CENTER ENABLES THE STUMP TO SERVE AS A FLOWER POT FOR SEVERAL MODERN PLANTS.

With its hundreds of tree species struggling for the same area, its dozens of climber and epiphyte species clinging to the tree tops to secure a place in the sun, its profusion of bird, beast and insect life, its innumerable types of ticks, lice, fleas, tapeworms and other animal parasites which live upon the different animals, its daily surge of plant and animal activity, the moist tropical region offers the most excellent field in the world for the study of nature in the making. It is no wonder that in pursuit of their studies of nature in the moist tropics, Charles Darwin and Alfred Russel Wallace were convinced of the reality of evolution and were led to an appreciation of the struggle for existence and the survival of the fittest as factors of importance in the explanation of the process.

The student of tropical life, however, does not find every organism perfectly fitted for its place in the world. With such great diversity, we could hardly expect equal degrees of fitness. On stepping outside the laboratory one rainy day, the writer saw a portion of the forest roof in the valley below him topple and heard a great crash. A visit to the place showed that a big tree of the ginseng family had broken into a thousand fragments. The brittleness of the wood, the increased weight of the water-soaked leaves and blossoms, the loosening of the soil by a week of unusual rainfall had conspired to effect in a moment the ruin of an individual which had been a century in building. Every day the jungle offers evidence that some species are in certain respects lacking in fitness, yet are not unfit enough to disappear entirely from the scene.

One is likewise strikingly impressed with examples of greater fitness. One day while paddling about the shores in the hollowed log canoe, the writer saw far out in the lake a big tree that seemed to have an unusual number of orchids growing upon its limbs. On going

ONCE AN EPIPHYTE, NOW A FOREST GIANT

THIS MAMMOTH FIG TREE (*Ficus costaricana*) STARTED LIFE IN THE CROTCH OF A TREE OF THE BRAZIL-NUT FAMILY. DROPPING ITS ROOTS TO THE GROUND, IT DEVELOPED A LARGE TRUNK ENTIRELY SURROUNDING THE TREE THAT SUPPORTED IT IN INFANCY, BUT SOME OF THE BRANCHES OF THE LATTER COULD BE SEEN ABOVE THE RANGE OF THIS PHOTOGRAPH. NOTICE A PROP ROOT IN THE FOREGROUND AND ANOTHER AT THE RIGHT.

SAPROPHYTES IN TROPICAL RAIN FOREST

AT THE LEFT IS *Ophiomeris panamensis*, AN INTERESTING AND RARE PLANT OF THE BURMANNIA FAMILY. AT THE RIGHT IS *Leiphaimos albus* OF THE GENTIAN FAMILY. ONE SPECIMEN OF OPHIOMERIS IS IN ITS ORIGINAL POSITION, THE OTHER PLANTS HAVING BEEN TRANSPLANTED FOR THE PICTURE. THESE PLANTS, WITH THE COOPERATION OF A ROOT FUNGUS, MAKE USE OF THE DECAYING MATTER OF THE SOIL.

nearer it was a real surprise to note that the tree itself was alive. It was a Bombacopsis, of that species to which the biggest trees of the forest belong. Standing in about sixty feet of water for the past thirteen years, with its trunk flooded to the crotch, the bark which had died and disappeared below the water had healed over at the water-level and had sent into the water a few feeble roots. These roots have sustained a few twigs and have enabled the tree to hold the slender thread of life under conditions which would utterly discourage most mortals. Perhaps this explains why Bombacopsis gets to be so large a tree in the forest. At any rate, we have here presented an example of hardihood and tenacity that would be difficult to equal—an example that should induce us in the midst of discouragements to push forward more thoroughly impressed with the beauty and the majesty of life.

NATURAL HISTORY BY RADIO[1]

THE LARGEST REPTILES

By Dr. THOMAS BARBOUR

MUSEUM OF COMPARATIVE ZOOLOGY, CAMBRIDGE

MANY millions of years ago there were no warm-blooded animals on the face of the earth, and the principal creatures to be met with on land, at sea, and in the air were reptiles. There were gigantic, browsing, lizard-like reptiles, bulky bodied and slow moving, which reached a length of 150 to 180 feet and which would weigh more than several elephants. There were great hopping kangaroo-like forms, some of which had long tearing teeth. These fed upon the passive, sluggish and inoffensive types—large though these were. Then there were gigantic armored reptiles which looked more as the rhinoceros looks, and in the sea, schools of porpoise-like reptiles dashed after their finny prey—for fishes, of course, were abundant even in these ancient times. There were no birds, but their place was taken by flying reptiles which ranged in size from little sparrow-like creatures to enormous forms whose spread of wing would rival or exceed that of the largest flying birds which we know now.

Times have changed slowly but surely, for many millions of years have passed and the reptiles are not now the dominant creatures which they were once, and to-day, with ever-accelerating pace, conditions change faster and faster. The tropical jungle, over vast areas, is being cleared for the planting of such products as sugar, coffee, rubber and bananas, and with the clearing of the forest the old jungle life goes. Millions of men, whose fathers hunted with the bow and arrow, in many parts of the world to-day have modern rifles and shotguns, and, contrary to what many people believe, there is no alligator or crocodile so heavily armored but that the modern rifle can penetrate through and through his body, wherever he may be hit.

We have started to talk about crocodiles and, while nowhere in the world are there to be seen such monsters as could have been found even a hundred years ago, nevertheless in the tidal swamps and marshes of the East Indies there are probably still a few old crocodiles over 20 feet in length. As I write these remarks, I am looking at the skull of the largest recorded crocodile in the world. It was killed 100 years ago near Manila by Mr. Russell, one of the old firm of East India Merchants. This great crocodile had long been known and was a terror to every native. Its lair was near a ford, and it had a way of pulling down horses and men as they rode across the river; sometimes frequently, and sometimes not for long stretches of time. Finally, by the concerted efforts of Mr. Russell, a French companion and a host of natives, the great beast was wounded, lassoed, drawn up on the bank, and dispatched. This great crocodile was almost exactly 30 feet in length and was no less than 11 feet around the body just behind his fore limbs. Mr. Russell brought the skull back and gave it to the Boston Museum of Natural History, where it was preserved for about 80 years, when it was transferred to the Museum in Cambridge.

[1] Broadcast under the auspices of the Boston Society of Natural History under the direction of Dr. Francis Harper.

No alligator ever approached this size. In the past there have been many 16-foot alligators in our southern states. Today a 12-foot alligator is rare, and the great majority are 6 to 8 feet long. During the last two or three decades, thousands upon thousands of alligators have been killed for their hides and many thousands more have been left without breeding grounds by the draining of the Everglades and other swamps.

Many winter visitors when they go to Florida bring young alligators as pets and these little animals, kept under unfavorable conditions as they perforce must be in the north, grow very slowly or not at all. Kept out doors in a garden fountain during the summer time they grow rapidly if abundantly fed, but during the rest of the year they do not grow at all. This is probably one of the reasons why people believe that a really big alligator must be hundreds and hundreds of years old. Big alligators may live for a long time. Of course no one knows definitely. We do know, however, that under really favorable conditions of climate and food they grow very fast. Little alligators hatched in the reptile house of the Zoological Park in New York in 1900 were six feet long and weighed nearly 75 pounds at the end of six years. An alligator, just under seven feet, which came to the park in the autumn of 1899 was eleven and a half feet long by the autumn of 1905. This animal may have been perhaps fifteen years of age. So that we can say with certainty that a twenty year old alligator is fully grown. We have no such accurate data for the crocodile, but there is no reason to suppose that its rate of growth would differ very much.

It is not generally known that there is an alligator very much like our southern species found in east central China. It seems to be a smaller form, growing only to be four or five feet long. This small size may, however, be due to the fact that it is constantly hunted and persecuted by the Chinese who use almost every part of the animal for medical purposes. If, as is not impossible, they were much more abundant and grew to a far larger size generations ago, it is not improbable that this alligator was the prototype of the Chinese Dragon which was so abundantly used in decoration and so often referred to in Chinese folklore and mythology. It is interesting that the Chinese 'gator bears two names You Lung and Tou Lung, both of which combinations signify a dragon. Unlike our species, the Chinese alligator is very shy, coming out only after dark and preying largely on the mongrel dogs so common everywhere in China. Our own alligators love to bask in the sun, but where persecuted they too tend to become nocturnal.

You have all heard of the great tortoises of the Galapagos Islands. These, with their cousins found on some small islands in the Indian Ocean, are the largest of all the land turtles. We know that they live to very great ages, for there have been specimens in captivity at Cape Town, in Ceylon, at St. Helena, and in Mauritius for over a century. The largest of these turtles will weigh perhaps 450 pounds and be about 4 to 4½ feet long and perhaps 3 feet high—great, ponderous, unwieldy creatures. There is a fossil turtle known from India which was very much larger than this.

Sea turtles are larger than the existing land tortoises (the name turtle and tortoise are perfectly interchangeable terms). The great turtles which live on the surface of the tropical seas and occasionally wander elsewhere, may be 8 or 9 feet long and weigh 1,400 to 1,500 pounds.

The majority of present-day lizards throughout the world are small creatures, but a few years ago a gigantic lizard was found to persist on a little island called Komodo, far to the southeast of Java, and this great brute,

which may grow to perhaps nine feet in length, is said to kill pigs and even at times to attack the native ponies. Recent expeditions have taken many of these monitors, none of which reached the size indicated by the first rumors of their existence. Except for this giant there are but few lizards more than 4 feet in length. These are found among the families of the old world monitors, all related to the Komodo Island lizard, and amongst the iguanas of tropical America. Such iguanas live in trees, are vividly colored and rather terrifying to look at, with their crests of long spines and horny tubercles. Never-the less they are very delicious when properly cooked and are eaten by very many different peoples, including the writer, who has enjoyed them on many occasions.

Snakes do not grow nearly as long as some travelers tales would have us believe. The longest poisonous snake is the great King Cobra of southern Asia which once in a great while reaches 18 feet, but the crushing non-poisonous species grow much larger than this. The Pythons (sometimes wrongly called Boa-constrictors) in the Malay jungles grow to be about 30 feet at most. The largest of the true Boa-constrictors are very much smaller, probably never reaching 18 feet, although in the rivers of South America the Anaconda grows to the greatest size of any living snake, reaching 35 and possibly even 40 feet in occasional cases. Such a snake as this would weight about 325 pounds or perhaps even more.

Under what might be called normal conditions the snakes and lizards, as well as turtles and crocodiles, lay eggs. These may be buried in the sand or mud; a nest of decaying vegetable trash may be laid up in a sunny spot; the eggs may be buried in sand banks, in hollow trees or in cavities in rotten logs. They are hatched by the heat of the sun, aided frequently by the heat generated by decaying vegetable matter. I am often asked, "How is it that a good many snakes and a few lizards have living young?" and the answer is simply this; that in a certain number of forms the eggs are retained within the body of the parent until they hatch. The young emerge and the egg capsules may be cast forth later on or be absorbed. Generally speaking, most poisonous snakes of the viperine type, *i.e.*, those that have long movable fangs, have living young, but some harmless snakes, as our common water snake, for instance, also bears an enormous living brood, sometimes even fifty or sixty. The habit, while common with snakes, is a very rare one among lizards and is unknown among tortoises and crocodiles.

It is perhaps needless to say that snakes do not swallow their young to give them protection, although I know that a lot of you have friends that know someone who saw this happen. I hear of such cases all the time, but curiously enough the naturalists who are in the field year in, year out, observing the habits of reptiles in every part of the world have never yet seen a single case where this occurred. Sometimes, during the common country pastime of beating a useful snake to death with a club, the young about to be born may be squashed out of its body and, of course, the average person can only interpret this by assuming that the little snakes got where they were found by running down their parent's throat after they had been frightened. This yarn, until more evidence is accumulated, will have to be classed in the same category with the story of the hoop snake, and the coach-whip snake and similar whimsies.

The part of the world in which we live—these New England States—are not very plentifully populated with reptiles. None of the giant species occurs. The poisonous snakes have almost completely disappeared except for a few scattered localities where an occasional

copperhead or rattlesnake may be found. Our little pond turtles and land tortoises are familiar to every country boy and girl, although there are many who have never seen a lizard alive, unless it be some hapless little captive brought home from a trip to the south. Nevertheless I know that you all know enough about the general form of these different sorts of reptiles to be able, in some degree at least, to see in your mind's eye the giants of the hot, moist, equatorial lands.

WHALES AND WHALING IN NEW ENGLAND

By Dr. GLOVER M. ALLEN

BOSTON MUSEUM OF NATURAL HISTORY

THE early history of New England is very closely bound up with the whale fishery, an industry to which our early colonists applied themselves with such zeal that at one time in Massachusetts Bay it bade fair to be one of their best sources of revenue. The historic *Mayflower* herself, even before she sailed on the eventful voyage to Plymouth Bay, had apparently been a whaler and in after times was for a number of years engaged in the Greenland whale fishery. When, therefore, in 1620, the Pilgrims found an abundance of whales "playing hard by," many of them were eager to undertake their pursuit, especially as there were among the ship's company a number of men skilled in the Arctic whaling, a much more difficult profession. The whales that frequented our shores in such numbers three hundred years ago were of the kind called "right whales," a peaceable and relatively slow moving species, provided with a thick coating of fat or blubber over its body, and with long narrow blades of whalebone hanging in double rank from the roof of the mouth. These whales were migratory, appearing on our coasts in late October from waters farther east and north. No doubt many remained all winter while others went still farther south, even to the Carolina coast, and returned northward in spring, especially in April and May, often at this season accompanied by their young. In these early years dead whales were so often cast upon shore, that laws and regulations for deciding their ownership were constantly being enacted. For some years, the coast towns of southern Massachusetts regularly appointed a "whale viewer" whose duty it was to examine all such "drift" whales as they were called and to record all marks or wounds upon them, as well as to keep a record of whales reported to have been wounded but lost, so that in the case of their being subsequently cast ashore, the rightful owner might be enabled to claim them. In 1662 it was voted by the town of Eastham that a portion of the proceeds of all such whales as drifted ashore dead from natural causes, be appropriated for the support of the ministry. Subsequently, in 1702, the Reverend John Cotton, of Yarmouth, received no less than £40 from the amounts realized for whales so cast up. The pursuit of whales in small boats from shore continued for over one hundred years until the numbers of those frequenting our coasts were very much depleted and they have never since recovered. Most of the pursuit of whales was at first in small boats from the shore, and in this a good many of the Cape Cod Indians were regularly employed, becoming skilled in this work. Gradually, however, the colonists began to fit out small

vessels for the pursuit of whales off shore, and it was in the course of one of these voyages to the south of Nantucket, that Sperm Whales were encountered in the warmer waters of the Gulf Stream. So that when, about 1750, the pursuit of "right whales" near shore was no longer profitable, there were men and vessels ready to go on longer cruises for the sperm whales. This industry developed rapidly. In 1774 ships from Nantucket first crossed the equator in pursuit of whales, and in 1791 the first American whaler rounded Cape Horn into the untried whaling "grounds" of the Pacific. The many vessels that followed, especially from Nantucket and New Bedford, carried our flag into all parts of the sea and many a Pacific island was first hailed by the daring old masters of these vessels. The whaling industry in New England reached its zenith about 90 to 100 years ago, but with the discovery of kerosene for light, it collapsed almost entirely, though a few vessels have continued to sail from New Bedford almost to the present day, chiefly in pursuit of sperm whales and bowheads, the latter among the floe ice of the Arctic regions.

Now, however, the whalers are few and little remains but the traditions of a once flourishing business.

> Adze and hammer and anvil stroke
>   Echo not from the shore;
> The wharves are old and broken and gray
>   And the whaleships come no more.

Most of us now-a-days have seldom seen a whale either dead or alive, and fewer still can tell the different kinds. All sorts of questions are asked—Is a whale a fish? What is the spout? What kind of whale swallowed Jonah? From the standpoint of a zoologist a whale is not a fish, but a mammal that has become adapted to life altogether in the water. Whales are warm-blooded, bring forth their young alive and suckle them. Within a few years fossil whales of great antiquity have been found in the early Tertiary formations of Egypt that give us certain of the links between the more typical whales and land mammals, and indicate that the group sprang from one of the older stocks of flesh-eating mammals. As a result of their aquatic habits, whales have developed the tail as a swimming organ, have lost their original coat of hair except for a few bristles in some species and have entirely done away with hind legs. The place of a hairy covering is taken by a thick layer of fat or blubber. Nevertheless, from a legal standpoint, it was decided over 100 years ago that in the State of New York a whale is a fish. It seems that in those times the State levied a tax on fish oils brought into its territory. Importers of whale oil, however, refused to pay a tax on this product on the ground that a whale was not a fish, and the law therefore did not apply. The case was tried at length in court, and a decision reached that for the purposes of the law a whale was a fish and its oil was therefore fish oil subject to tax. Whales breath air like other mammals. How then to account for the spout, rising like a jet of steam when the animal comes to the surface? This spout is merely the condensing moisture of the breath, which, expelled with great force, expands rapidly and thereby is momentarily cooled below the temperature of the surrounding air causing the vapor to condense and become visible.

Whales have usually but a single young one at a time, born alive at the surface of the sea. The young whale is about one third the length of the adult at birth and is suckled by the mother for several months.

Whales are readily divided into two chief groups, the first comprising those with teeth, the second those in which the teeth have been lost and from whose palates hang the whalebone plates in two lengthwise series. Of the first group the Sperm Whale is the largest species, but

it is rare in New England waters. The lower jaw only has functional teeth that fit into sockets in the upper lip. Sperm whales feed largely on squid, at times attacking and eating the giant squids, portions of whose huge tentacles are sometimes found as leavings from a Sperm whale's meal.

To this same group of toothed whales belong the various smaller species of dolphins and porpoises, including the so-called blackfish familiar to Cape Cod folk, a species that occurs at times in summer in large schools, which may be driven ashore and stranded.

The second group is called the whalebone whales, and includes six species within our limits. Of these the right whale is the one formerly so much hunted on these coasts, a stout chunky slow-moving whale, attaining a length of some fifty feet, with the upper jaw much bowed upward to accommodate the long whalebone plates which in the middle of the series have a length of about seven feet. The use of the whalebone is to strain out the minute crustaceans and small free swimming mollusks on which the whale feeds. Great masses of water are taken into the whale's mouth and by the closing of the mouth are forced out through the matted hair-like threads at the free ends of these whalebone plates, leaving the food behind to be swallowed. The much larger Arctic whale or bowhead has the upper jaw even more arched than in the right whale to accommodate its 15-foot plates of whalebone. This species is confined to the Arctic Seas. Of the other five whalebone whales on our coasts, one, the humpback, has an enormous fore flipper, equalling about one third of the mammal's length—some 45 feet. This whale is a particularly agile species, often performing many strange antics, thrusting one fin out of the water or lashing its tail violently, again rising almost straight up in the air, to fall over on one side with a resounding splash. The four other large species are long and slender in form, the throat as in the humpback is thrown into lengthwise pleatings or folds which allow of a considerable expansion as the whale opens its mouth to feed. The common finback, attaining a length of 65 feet or more, with a high fin on the lower part of the back, is the one most often seen, for it frequently comes into Massachusetts Bay especially in summer to feed on the shoals of herring or the quantities of small shrimps found near the surface. A similar but smaller species, the northern fin whale, is rare with us but may at once be distinguished by its whalebone, which is black, fraying out into fine white threads. Still a third is the small grampus whale, easily told by the large white bar across the fore limb and by its short pale-yellowish whalebone. Last of all is the great blue whale whose appearance in our waters is not satisfactorily known, though it occurs commonly off Newfoundland and has been cast ashore as far south at least as New Jersey. In this species the whalebone as well as its frayed ends is black. It has been known to reach a length of slightly over 100 feet, the largest living mammal.

All five of these finwhales are quicker in movements than the right whale, so that the larger kinds can not easily be killed with simple harpoons and lances, for so swift are they that they would very soon drag a boat under or overset it. They are killed, however, by means of heavy harpoons with an explosive charge, shot from a gun. The fat of the Blue Whale contains a large percentage of glycerine, used during the war in making explosives.

Concerning the movements and occurrence of the whales mentioned we know relatively little, hence those persons living on the shore who have a chance to see whales might help in the securing of valuable information by sending their observations to the Boston Society of Natural History, taking especial notice,

where possible, of the size, color of whalebone and its frayed ends, the presence of folds on the throat, the number of teeth or other points. The accumulation of such facts may in time be of much scientific importance.

SOME COMMON INSECTS OF THE HOUSEHOLD

By CHARLES W. JOHNSON
BOSTON MUSEUM OF NATURAL HISTORY

HOUSEHOLD insects is a somewhat popular term given by authors to all insects that may happen to frequent houses. When we realize that as household pests these are unnecessary and that in a well-kept house they are really absent, a much better term would be—insects that sometimes frequent houses. These insects can be divided into three classes: (1) those that actually breed within the house, such as cockroaches, bedbugs, clothes moths and carpet beetles; (2) those that breed outside and are attracted inside by food, including the house-fly, blow-flies, fruit-flies, ants, etc.; and (3) a group of insects that enter houses in the fall only to hibernate, such as the cluster fly and other allied forms.

The presence of those actually breeding in the house is usually the result of carelessness of the housekeeper, or if in an apartment, probably that of a neighbor who leaves dirty dishes and food around promiscuously—this being just the place cockroaches revel in.

You can see the roach a'waving its feelers with delight
When it finds that the jam jar is not closed tight.

A woman in not the most pleasant tone once said "I have no roaches in my house, only water-bugs." Now the water-bug is a little roach (*Blatella germanica*), often called the Croton bug as they became very abundant shortly after the completion of the Croton Water System in New York City in 1842. The Oriental cockroach (*Blatta orientalis*) and the American cockroach (*Periplaneta americana*) do not thrive as well in this latitude as further south, but in some steam-heated buildings they are liable to survive the winter. There is an old saying that it is no disgrace to have certain bugs in the house, the disgrace is in keeping them. A house that is kept thoroughly clean furnishes no suitable environment for these insects. With a thorough cleaning once a week there is also little danger from either clothes moths or carpet beetles.

A very primitive wingless insect that sometimes appears in numbers, especially in dark closed rooms, is the "fish moth" or "silver fish" (*Lepisma*) so called from its peculiar scaly, fish-like form. I much prefer the term bristle-tail, a name that refers to the three caudal bristles. These insects are sometimes destructive to starched clothing, glazed paper and book covers, particularly where starch paste has been used. They avoid light and are very susceptible to the odor of naphthaline, very little of which in a drawer will act as a repellant.

Among the intruders that live outside our houses, the flies are perhaps the most troublesome. There are many species of flies that closely resemble each other, yet in their habits differ greatly. Thus there is much confusion among people regarding the true house fly (*Musca domestica*). Some of these flies are parasitic and useful in destroying injurious insects, e.g., the compsilura fly introduced from Europe to destroy the gypsy moth. Fortunately the para-

sitic species rarely enter houses, thus escaping the notorious "fly swatter." One of the flies that enter houses only to hibernate is the Cluster Fly (*Pollenia rudis*), so named from its habit of gathering in great numbers on the windows. They will often enter in numbers regardless of screens, having crawled in through some small crevice. There appeared in 1922 a European fly *Muscina pascuorum*, larger than the house-fly and bluish black in color. Its habits are similar to those of the cluster-fly and it may prove to be as great a nuisance. The closely allied stable fly (*Muscina stabulans*) though less abundant, so closely resembles the house fly that it is usually mistaken for that species. How can you tell the true house fly, some ask. Well, there is one very good test. If a fly alights on cooked food, nine times out of ten it is a house fly. It is this habit that makes this fly a menace to health. The possibility of its carrying typhoid bacilli is so great that many prefer to call it the "typhoid fly." The name seems somewhat inadequate, as this fly is also liable to carry many other diseases that may be prevalent.

Persons are often greatly alarmed by seeing hundreds of little flies on their windows, fearing that these small flies will grow to be larger ones. This idea seems to be quite general. They forget, if they ever knew, that all flies are first maggots and that all growth is in that stage. When an insect has wings it is full grown, even if no larger than a pinhead. These little flies are fruit or pomace flies (Drosophila) belonging to a different family from the house fly. They are attracted by decaying fruit that has been overlooked and by neglected garbage cans containing refuse fruit in process of fermentation. These little flies, being attracted by the fermented juices of fruit, might be useful in detecting those who are over zealous in making "home brew." All an officer would have to do would be to watch which way the flies go.

Among the country people there is a common expression—"It is going to rain, the flies are biting." This is due to the presence of the cattle fly (*Stomoxys calcitrans*) that so closely resembles the house fly as to be called the "biting house fly." In England it is commonly called the "storm fly." This is not a house fly, but lives in the fields and frequents cattle in large numbers. On the approach of a storm the flies leave the cattle and seek houses for shelter. The blue-bottle flies (Calliphora) and the gray flesh flies (*Sarcophaga*) are usually attracted by meat that should have been put in the refrigerator before becoming so attractive. The green-bottle flies (*Lucilia*) which are often called "fish flies" on account of their preference for fish, are often abundant, but all flies are less numerous than in former years, owing to the enforcement of better sanitary measures.

Ants are another group of insects that are attracted by food, especially sweets. The smaller species usually live in the ground or under stones or boards, but the large carpenter ants (*Camponotus*) deserve more consideration. If they appear in your house you should endeavor to find out just where they have their nest, for they some times desert a hollow tree (their natural home) and take possession of a house and completely riddle the timbers with their galleries. It cost a friend in Brookline over a thousand dollars to repair the damage done by these ants.

There is another insect that often destroys the timbers of buildings known as Termites, commonly called "wood-ants" or "white ants." These are not true ants, but belong to a much more primitive tribe of insects. In the tropics they are very destructive to all kinds of timber, but this far north where we have but one species, only timber that is near or in contact with the earth is injured. Houses on the seashore where the sand drifts against the woodwork are apt to be attacked by these insects. The pres-

ence of a swarm of the winged form in the late spring or early summer is a good indication that you have in the timbers of your house a thriving colony that demands prompt attention. This swarm of winged individuals have in no way lessened the danger, however, for these do no material damage. It is the large army of workers left behind that really cause the destruction and if these are not promptly removed the results may be like that which happened to a man in Philadelphia. A swarm of the winged form appeared in his parlor and he was warned of the damage that might accrue to the woodwork, but they soon disappeared and he paid no further attention to the matter. Next year another swarm appeared and a short time afterwards I heard that the piano had dropped to the cellar.

There is another group of insects that infest cereals and other dried vegetable products. These are also included among household insects, but are more abundant and troublesome in granaries and warehouses. The meal worm, the larva of a black beetle (*Tenebrio*), is common in feed stores and around stables. Meal is also infected by the Indian meal moth (*Plodia interpunctella*), while the common meal moth (*Pyralis farinalis*) feeds on both meal and grain. Flour is often infested with two or three species of little brown beetles popularly known as flour beetles, while the more recently introduced Mediterranean flour moth has become quite prevalent. Grain is often injured by the grain weevil (*Calandra granaria*) and the rice weevil (*Calandra oryza*). Beans are infested by a particular kind of weevil (*Mylabris obtectus*), and peas by a similar species (*Mylabris pisorum*). One of the most interesting insects belonging to this group is the Angoumois grain moth (*Sitotroga cerealella*). Its close resemblance to the clothes moth is often the cause of alarm among housekeepers. I once visited a friend in Pennsylvania who was very much excited over what she thought were clothes moths. Noting that these were a trifle larger than that species, I said, "Have you any popcorn?" She thought a moment, and then went to a small closet above the kitchen range. On opening the door she was greeted with a swarm of moths. There were only a few ears of corn but the kernels were riddled. It seems surprising that so small a caterpillar could devour so hard a substance.

Where herbs were more generally used in medicine they were often injured by several small beetles. One known as the drug store beetle (*Sitodrepa panicea*) is still prevalent, feeding on all kinds of dried substances. Another that feeds largely on tobacco, ruining cigars and cigarettes, has become popularly known as the cigarette beetle (*Lasioderma serricorne*). This is not as common as the drug store beetle, probably because the smokers do not give it a show. I was describing this little beetle to a friend who was no lover of the cigarette and he said: "I call that a beneficial insect. It should be encouraged." Evidently there is a difference of opinion as to what is an injurious and what a beneficial insect. Little beetles known as spider beetles (*Ptinus fur*) also feed on various dried materials. In November 1920 a party brought me one of the spider beetles (*Niptus hololeucus*) which he was finding in considerable numbers in his house, especially in the bathroom. Their presence in the bathroom could be explained by the fact that the steam heat had made the rest of the house too dry for their comfort, while the bathroom presented more humid conditions. The presence in Boston of this European beetle which had only been recorded in this country from a house in Montreal was difficult to explain. That there was something in the house on which these beetles had fed, was evident, but a thorough search

by the owner revealed no object that was infected. The following November they again appeared in lesser numbers and then practically disappeared.

In referring to the various insects I have not dwelt on insecticides for it seems unnecessary. No doubt many of the insect powders, are good of their kind but you must do your part. When people say, "We have tried everything and still they are there," all I can say is, Have you thoroughly cleaned your premises? If they say yes, well, I hae ma doots!

FOSSILS—WHAT THEY ARE AND THEIR USES TO MAN

By Dr. J. A. CUSHMAN
SHARON, MASSACHUSETTS

You probably think that a fossil is one of the most useless things in the world. How often have you heard a person spoken of as "an old fossil." It isn't complimentary, but to give the idea that the person is behind the times and not interested in up to date things.

Fossils are remains of either animals or plants that have lived in the past, and left traces in the rocks. If you go into the Museum of the Boston Society of Natural History, you will find there some large slabs of red sandstone. These came from the Connecticut Valley and are millions of years old. Once they were wet sands. On these slabs may be seen footprints of animals that walked across the muddy sand while it was still soft. You can measure the length of step from one footprint to another. Some of the animals were large, and across the same slab are the tracks of much smaller ones. There are also fine markings where worms or crabs crawled across the mud, and perhaps the larger animals were after these. Then a shower came up, and you can see the marks of the raindrops. One side of the raindrop marks is deeper than the other, showing which way the wind was blowing at that time. So you see, from this slab of rock, you can with your study and imagination tell many things that took place in that far away time. It is really a record written on the slab of rock that one who is trained in the language can read.

Fossils have been preserved in many strange ways. You all have seen amber beads. Amber is the gum or pitch from trees that lived long ago. It has been preserved all this time. In those days, insects of strange kinds crawled up the tree trunks and became stuck in the gum. More gum oozed out and covered them. So in some amber there are preserved these insects of older times with all the perfect details of their delicate wings.

In California there are pits where asphalt-like material is dug out. It is now hard, but thousands of years ago it was soft and sticky. Different kinds of animals got into these sticky pools and died, leaving their bones in great numbers. Thousands of these bones have been gathered, and as a result, we know a great deal of the animals that roamed about in that part of the world many thousands of years ago.

You have all seen shells along the beaches and have seen how easily they are buried in the sand. This same thing has been going on along the shores of the oceans for millions of years. Later, these deposits may have been raised far above sea level, and these sea shells are then found high up above the present level of the ocean. Such rising and fall-

ing of the land and sea level has been slowly taking place as far back as we have any record in the rocks of which the earth is made.

But you may be saying, "Of what real use are these to man at the present time? It may be interesting to know about the queer animals of the past, but how does that really help us today?"

You may not at first believe it, but most of our modern life, especially city life, depends upon these fossils of the distant past. Due to fossils, you heat your home and school buildings, have electricity with all that means in your every-day life, run automobiles and trucks and trains, have the thousands of varied colors in dress goods, asphalt streets, and so on and on. Do I hear you say that these things come from coal and oil and other things that are not fossils? Then let us see. What is coal? It is the remains of fossil plants that lived far back in the Carboniferous period, an early stage in our world history. In the coal, and especially in the slate above and below the coal beds, are the remains of trunks of tree ferns and their leaves. The coal beds are the result of fossil plants. Then all the varied uses of coal that you can think of depend upon fossil plants. Gas is made from coal, so if your dinner is cooked on a gas stove, you are again using fossils indirectly. You have heard of coal tar products, and of aniline dyes, again coal fossils. Many medicines and such things as vaseline and different kinds of wax are obtained in the same way. Even perfumes and flavorings can be made from this same source. You can see how dependent you are upon these fossil plants.

It is often said that this is the age of gasoline. Here again, gasoline is made from crude oil which is taken from deep down in the earth where it has accumulated for a long time. The oil is made from fossil plants and animals that lived a very long time ago. Think of all the uses of gasoline, naptha and kerosene, and see what you owe to these great numbers of tiny animals and plants that lived so long ago. There are hundreds of products that are made from crude oil, and hundreds more will be produced just as soon as a use is found for them.

Fossils can be used to help find oil. Each different layer of sand and clay, sandstone or limestone of which the rocks of the earth are made have usually fossils in them. By long and careful study it has been found that the fossils in each different layer differ from those of other layers. They also have the same differences over wide distances. So if a sample of limestone or shale is given to a trained worker, he can tell from which layer in that region it came. Now, if it is known that oil occurs in a certain sand the position of which is known in the section of the earth, it is possible to predict how deep that sand is below a given place by a study of the fossils near the surface. It is as if you knew that John Smith, the grocer, had his store on the second floor, and Tom Jones, a shoe dealer, on the sixth floor. So when you find the sign of John Smith, and the elevator is not running, you know you have four more flights of stairs to climb to reach Mr. Jones, the shoe dealer. So if the oil layer represents the second floor and we find the fossils that show we are on the sixth floor, it means going down four imaginary flights of stairs to get to the oil layer.

Many limestones are made almost entirely of the shells of fossil animals that were buried in the muds of the ocean in past ages. These become cemented together and hardened. Then they are raised far above the sea as mountains are built. If they have been heated and pressed enough in this process, the limestones are turned into marble. So the beautiful monuments and buildings may owe their beauty of form and color also to fossils.

The chalk you use in school, if looked at under the microscope, will be found to contain the shells of tiny fossil animals. The phosphate beds of the Southern States, which are dug out to help make fertilizer, are made up largely of the bones of fossil animals.

If I should ask you to name the largest things ever built by man, probably you would say, "The Great Pyramids." They are undoubtedly the greatest in size at least, and have been looked up to for thousands of years with wonder that man, who is himself so small, could have built these mighty structures. The greater wonder is that he could have done it without the modern machinery we have to-day. Yet hundreds of thousands or millions of years before, other builders were at work getting the material for the pyramids ready for man. They were some of the simplest and lowest forms of animals that we know anything about. They lived in great numbers in the warm seas in that far away time, and their shells by uncounted millions built up the thick limestones. Later, these were raised above sea level in the hills along the Nile, where the workmen of an Egyptian Pharaoh cut them out and built the pyramids. So the mightiest monuments man has ever built are made of limestone built up of fossils of some of the smallest animals that we know anything about.

Perhaps this will be enough to show you that a fossil is not to be looked upon as something that has lost its usefulness, but may after all have been only getting ready for real use.

THE PRESERVATION OF SCENIC BEAUTY IN TOWN AND COUNTRY[1]

By VAUGHAN CORNISH, D.Sc.

SCENERY, the outdoor view, is the aspect of the world which all men have in common. Its true beauties, the aspects more than pleasing which fill the mind with joy, result from combinations which produce mutual enhancement of the parts, harmonics in the full sense of the word.

The scenery of a country is artificially modified from generation to generation, and it is necessary therefore that we of the academic world should discover and define the combinations which result in scenic beauty if we are to take the responsibility of advising on measures for its preservation. We have, in fact, to lay sure foundations for an esthetic of scenery.

Great Britain's heritage in scenery is of town and suburb, village and farm, wild waste places and the splendid setting of the sea, all under the canopy of soft skies given by oceanic climate.

SCENIC HARMONIES OF THE TOWN

The characteristic beauty of the street is the effect of a vista, the pleasant path by which the eye follows converging lines to a point of rest in the far distance. Piecemeal reconstruction of streets is necessary in a progressive era, and, in order to preserve the dignity of the street, uniformity of cornice lines must be enforced by municipal authority; otherwise the vista vanishes, camouflaged by vertical strips.

The necessary increase in height of houses is reasonably lamented when disproportionate to width of thoroughfare, but the erection of lines of lofty buildings facing great open spaces is free from this drawback. The beginning of the epoch of steel-framed sky-scrapers has, it is true, the inevitable disadvantage of rearing isolated blocks which cut the sky harshly with square quoins, but as the type of building becomes more general these blocks unite in a long façade more imposing than any vertical plane in scenery except the cliff which rises sheer from the waters of the ocean.

Hearing that lofty steel-frame building had begun in Park Lane, I went to see the effect. In Victorian days I spent so many pleasant and idle hours on the shady lawns of Hyde Park between the Achilles statue and Grosvenor Gate that I grew fond of the irregular line of miscellaneous architecture seen through the plane trees and beyond the border of brilliant flowers. The new building dwarfs them all, and by breaking a pattern blurs the pleasant members woven into a view of which the pattern was a part. But this drawback was amply compensated by a new element of nobility in the scene, that of imposing loftiness, which was most felt when the new building was viewed through the bare boughs of the plane trees. I found also another improvement, for when looking across the open park with its spacious sky the presence of a lofty façade gave what was wanted to complete an opulent impression of general amplitude. I returned to the spot a few months later when the lattice of the boughs was improved by the perforated screen of half-opened leaves, and the satisfactory impression of the first visit was not only confirmed but strengthened. Yet what is happening

[1] Address of the President of the Conference of Delegates of Corresponding Societies, at the meeting of the British Association for the Advancement of Science, Glasgow, September, 1928.

makes many people shudder and prompts gloomy comment on the commercialism of the age. If Park Lane were destined to remain as it is at the present moment I would not undertake to say that the break in the pattern was pictorially justified, but I am visualizing the pattern as it will be when complete. Hyde Park will then be glorified by a long and lofty façade, as a spacious plain is more glorious if bounded by a range of mountains than a line of hills. Meanwhile the individual buildings will gain in the details of their structure as the artists gain greater mastery of the new medium.

In the great cities there are lofty outlook stations accessible only with much labor, as at the Monument and St. Paul's in London. In Edinburgh and elsewhere an Outlook Tower has been built through the prescience of Mr. Patrick Geddes. In the lifts which are necessarily installed in lofty steel-frame buildings, municipalities have ready to their hand a means of providing the public with easy access to outlook points selected for the beauty of their prospect.

The city skyline of spire and pinnacle is never more imposing than in misty air, which emphasizes outline as much as it diminishes relief, and the ruddy tinge of sunshine struggling through a pall of smoke confers excitement of color which counteracts the dulling effect of lessened light. But in our climate there will never be lack of misty days, and, even apart from considerations of health, we pay too dearly for the fine, lurid effect of smoke. The black coat on buildings obscures the shadowing to which cornice and colonnade owe much of their beauty. The growth of vegetation is so checked as greatly to impair the contribution of blossom, foliage and tracery of boughs which is desirable not only for its own beauty but as a foil to the insistent forms of architecture, multiplied in cities beyond the endurance and capacity of the eye. The effect of smoke is equally adverse to the social scenery of our cities, for, by screening the warmth, the brightness and the vitalizing rays of the sun, inducing fog and smirching every garment of fine texture and bright color, it militates against the habit of *al fresco* meals and social intercourse out of doors during hours of rest which adds so much to the scenery of cities in warm and sunny lands. When the pall of smoke is removed it will be found that the paving and surface draining of towns has lessened the drawback of our natural climate for sedentary outdoor recreation, which is mainly that of exhalation from damp ground. Moreover, the better growth of vegetation will bring something of country fragrance to the air of towns, the fragrance which has so strong an influence upon our esthetic mood and power of appreciating beauty.

The preservation of scenic harmony is never more difficult than where new construction has to be undertaken among venerable buildings. Yet such problems can be solved, as I learned when I lately went to Winchester to revive the memory of ancient beauties which I had not seen for thirty years. It was a perfect day in early spring, and Cathedral Close and College Precinct were seen in all their mellow charm. Noticing a new building in College Meads I turned aside and found myself within a cloister erected as the war memorial of Wykhamists. Here I felt the spirit of the past and saw an added glory to Winchester. There was neither lifeless imitation of traditional forms nor architecture so alien as to introduce incongruity. The roof of rough stone, suited to its exposure and pleasantly breaking up the sunlight, the good smooth stone and reposeful circle of the arches, the splendid message of the inscription to the dead which circles the knapped-flint walls of the cloister in letters of white stone shaped to the old Lombard script, are the satisfying out-

come of that cooperation between an artist and a scholar which should always be sought for construction in such sites. Moreover, the hand of the careful craftsman can be seen, the final satisfaction of the nearer view of architecture.

Scenic Harmonies of Suburbs and Seaside Resorts

Ever since our towns grew large, the city man longing for the sweet fresh air of the fields and the scenery of vegetation has sought a home in the situation bordering both the country and the town, but no sooner was he settled than the locus of these advantages shifted further out. By fixing a rural ring round the city and building compact suburbs beyond, the selection of a home permanently suitable for the average business man would be made possible for the first time since the beginning of the industrial epoch.

The present suburbs are often preeminent in garden decoration, especially in the tree blossom and flowering shrubs displayed to the road, but the scenery of social life is impoverished by radial building. The straggling suburb is inferior to the town in illustration of collective life and inferior to the country in illustration of the round of individual occupation. The detached suburb of compact plan, by providing better illustration of both individual and collective occupation, would remove the common reproach that suburban scenery is uninteresting. Moreover, we can plan its residential roads so as to combine excellencies which in Great Britain have hitherto been separately associated with the college, the mansion, the cottage and the villa. The plan to which I refer is well established on the other side of the Atlantic, where the admirable example of Toronto is fresh in the minds of many members of the British Association. The front gardens are not fenced from one another, and in consequence the detached villas stand in the dignified sociability of collegiate architecture. The avenue of shady trees by which the citizen goes forth to his work in the morning and returns at eventide is stately as the approach to a lordly country mansion. The front gardens with their flowers for all to see have the friendly brightness which is the charm of the English cottage garden open to the road, whilst the gardens at the back of the houses, adequately fenced from one another, give the privacy which is a cherished character of English villadom.

The large parks and heath lands now being replanned, sometimes with a central golf course, are free both from the bane of nineteenth-century building and from the pressure to conform to an earlier tradition. Here adaptations of a Mediterranean type of architecture, harmonizing with the landscape, are already to be seen. These embody the upper loggia and other facilities for shelter combined with open-air life. It can not be too clearly realized that this return to nature is an advance upon any of the earlier architecture of England.

The sea coast is our chief health resort, both for the annual holiday from business and for the restful years of retirement, and sometimes a suburb also for the city man. Half smothered in the modern growth of the seaside resort are the cottages of the old fishing village which was rightly placed to hug the shore. Here and there on our coast can still be found an untouched fishing village in a cove beneath the protecting cliff which preserves an unspoiled scene of the adaptation of occupation to environment. The general practice of developing the seaside resort on similar lines, with building front close to the beach, is however radically wrong. The building-line should be placed at the back of a broad lea, for a mere roadway and footpath between the houses and the beach is utterly inadequate as seaside pleasaunce for a considerable town, and the mind can with difficulty

receive the message of the free and open ocean amidst a jostling crowd. Fortunately, the more spacious planning is a counsel of economy as well as amenity, for the need for erecting costly sea defences is postponed, and meanwhile the growing population becomes better able to bear the financial burden.

Scenic Harmonies of Farm and Village

The country parishes of the English lowland have a decorative character unsurpassed in quiet charm. The land undulates, rivers flow quietly in gracious curves, there is wealth of broad-leaved trees of rounded form, and the fields are divided by bushy hedges where the natural vegetation is preserved. The preference displayed by cultured Englishmen during the eighteenth century for the scenery of prosperous agriculture was due in part to a shrinking from sterner aspects, but we have only to imagine the countryside as it was on the eve of nineteenth-century building (hurried, haphazard and largely in staring brick and poor slate) to realize that rural England of the eighteenth century would have held us enchanted by the perfection of its repose. House building since the great war has been even more rapid than in the nineteenth century. It is, as Sir John Russell remarked at a meeting of this conference, of a curiously mixed kind. The best houses are excellent in form, tone and color, and take their place in the landscape more quietly than the late-Victorian villa. The worst hold the eye against its will by harsh form and staring color, and, in many cases, by the conspicuousness of a site chosen for the sake of a wide prospect. While deploring such philistinism let us not forget that the Englishman's fondness for trees and love of privacy will largely remedy the present state of things. Experience tells us that in twenty years the little bungalow will be almost hidden in a grove, even though the view from the windows be partly screened.

In the great avenues of a well-planned city we have the stately effect of the vista, in many English hamlets and village streets the subtle charm of grouping which conforms spontaneously to the winding course of the valley's waterway, as beneath the Berkshire downs, on the Cotswolds and in the coombs of Devon. The preservation of this picturesque inheritance is fortunately made easier by the revenue derived from the motor industry which provides funds for the by-pass required for acceleration of traffic.

The winding country lane with overarching trees has long been a cherished possession of English scenery, in summer a corridor of cool green shade, in autumn an avenue of golden light, but we have never had Napoleonic roads bordered by league-long avenues and, as Professor Patrick Abercrombie has pointed out, the requirements of motor traffic provide the occasion for introducing this new element of beauty.

In the eighteenth century the traveler crossing England passed through a string of villages and large and small towns. Railways were, however, laid out so as to avoid villages and many of the smaller towns, so that the traveler of the nineteenth century rolled peacefully through mile after mile of verdant fields. The motorist of the twentieth century returning to the main roads receives a very different impression of the countryside, and consequently overestimates the recent encroachment on rural England.

If we leave the main motoring roads and also reject the cheapened charms of certain spectacular features of scenery, we find large blocks of agricultural England in which scenery is unaffected by recent occurrences. I lately visited a line of twelve country parishes lying on the slope of the West Berkshire downs overlooking the Vale of White Horse, places which I knew intimately

five-and-thirty years ago and had not seen since. There was no perceptible change in the lay-out of the fields, in the operations of agriculture, or in the architectural appearance of the villages. The light car had replaced the dog-cart upon the roads, otherwise all objects were as a generation since. One attribute of rusticity was, however, impaired, that of seclusion; the price paid for the rapidity and ease of access by car.

I have also gone back, after the lapse of more than forty years, to the village of Debenham in East Suffolk, where I was born and bred. Windmills have fallen into disuse and fewer handicrafts are carried on in the village street, but, throughout the thirteen-mile drive from the railway station, architecture and agriculture presented the same appearance as of old, even to the distinctive chestnut color of the cart horses and the manner of their harnessing to the plough. Visiting the school at Debenham, I found no apparent change of type. The true-blue eyes characteristic of the East Anglian stock preponderated as much as among the children of two generations back whom I knew in my boyish days. As I watched the school disperse, I felt that the charm of the high street was due as much to the blithe movements of happy children as to the statical background of old gabled houses.

The Needful Background of Wild Nature

Urban and agricultural scenery, though utterly unlike in decorative character, have the common element of human effort and contrivance. The scenery of wild nature from which this element is absent is not always more decorative than that of cultivated land. The landscape which is, perhaps, most satisfying for residence is that in which civilization is seen with ample background of the wild. But in many English counties there is no such background, for cultivation covers hill and dale. Therefore, as we can not everywhere view the wild, it is the more important to preserve such complete landscapes of untouched nature as we still possess, refuges where we can steep ourselves in the aspect of spontaneity with no reminder of man or his works. Nature and mankind are twin sources of inspiration, but the intimate and moving scenes of human life are not for the most part comprised in the outdoor view and do not therefore form part of the scenery of farm and city. Nature, on the other hand, though many of its wonders are microscopic, is most inspiring in the general view, and it is necessary for full development of the personality of a nation that the scenery accessible to the people should comprise the untouched elemental prospects which are unrivalled in their power to impart a reverent conception of the universe.

Of all the greater manufacturing countries with dense population, none equals our own in accessibility of coast and proportion of coast line to area. The sea shore provides a purely elemental prospect, the panorama of sea and sky with its unmatched horizon and never failing harmony of tone and color. The cliff by the sea presents from its precipitous verge an outlook unsurpassed even by Alpine scenery. Here from our island home we gaze upon a scene untouched by time, an image of infinity and eternity unequalled in its potential influence upon the loftier imaginings of our people. But although the view from the cliff can not be impaired, access to the view is often denied, and I submit that the time has come when no new enclosure extending to the cliff should be permitted and no further restriction of access allowed.

Education in Scenery

It is the duty of the academic world to educate the nation in the appreciation of its heritage of scenery. When

the benefits of scenic beauty are thus extended from the few to the many, the people themselves will guard the goodly heritage. The best method for carrying out this instruction in school is in connection with regional survey. The scenery of the home region has a more than local character, for it is almost an epitome of the scenery of the world, comprising the round of day and night, the response of vegetation to the seasons, forms of cloud common to all countries, the rising and setting of the sun and the revolution of the changeless constellations. Moreover, scenery appeals to the mind as a whole, for everything that we know about an object affects the way in which it appears to the eye, yet the feeling imparted by appearance is not limited by the bounds of knowledge. If the teacher will concentrate upon the perfection of characterization which brings the understanding of the heart, response among pupils will be widespread, for the esthetic faculty is latent in the generality, not, as the creative power of artistry, an exceptional endowment. Neither do the cares of poverty prevent the mind from dwelling on scenic beauty, as all who have traveled in Japan are well aware. There the coolie, whose standard of living is far below that of our working class, goes on pilgrimage to see each culminating beauty of the seasons, for the birthday of a favorite flower is a religious festival throughout the land. At the back of this are centuries of education in esthetic perception.

Those of us who aspire to be instructors in scenic beauty must submit to a certain discipline in order to acquire mastery of the subject. In our walks abroad we must let busy thought quiet down, that the mood of receptive attention may have full play. Then the whole being can be stirred, for the emotions aroused by scenic harmonies are far from being merely primitive; they result not only from inheritance but from the sum of all the past feeling, thought and action of a man's own life. It is only the jostling, obtrusive thought of the hour which is eliminated in the contemplative mood. To all who attain this receptive habit, the harmonies of scenery bring an integration of the personality which is beyond the reach of those who neglect the correlation and synthesis of thought and feeling.

The Necessity of Measures for Protecting Scenery

Our special function in regard to preservation of scenic beauty is research and education, but both processes require time, and the enemy, ugliness, must be held by a frontal force while we get round the flank. It is universally admitted that there are parts of the country where irreparable damage to scenery is needlessly threatened, and it therefore appears desirable that the British Association for the Advancement of Science should urge His Majesty's government to stimulate the employment by local authorities of the powers already conferred upon them by Parliament for the preservation of scenic amenity in town and country.

SURVEY OF THE LIFE OF LOUIS AGASSIZ THE CENTENARY OF THE GLACIAL THEORY

PREPARED UNDER THE DIRECTION OF DR. HENRY FAIRFIELD OSBORN

By HELEN ANN WARREN

ASSISTANT IN THE OSBORN RESEARCH ROOM, AMERICAN MUSEUM OF NATURAL HISTORY

Louis Agassiz arrived in America one year before the founding of the American Association for the Advancement of Science in September, 1847. He took a very active interest in the Association, served on its standing committee, attended meetings and contributed papers and addresses. He was also one of the founders of the National Academy of Sciences in March, 1863. A review of his life at the present time is of especial interest because of the centenary of the Glacial Age theory, which was developed between the years 1815 and 1837 by Charpentier and Agassiz and will constitute a prominent subject of the coming eighty-fifth meeting of the American Association for the Advancement of Science, to be held in New York, December 27, 1928, to January 2, 1929. The extraordinary difficulties encountered and surmounted by Agassiz in getting his start in science furnish also a splendid example to the highly pampered university youth of the present day.—HENRY FAIRFIELD OSBORN, *president of the American Association for the Advancement of Science.*

DURING the sixteenth century science was still an avocation of the man of wealth and leisure who could afford to dabble in peculiar phenomena, and of the man with an inborn love of puzzling out the secrets of nature, who was fortunate enough to interest some rich patron or publisher in his investigations. Physics and chemistry, astronomy, mathematics and medicine enjoyed a restricted vogue; the natural sciences, zoology, botany, geology and mineralogy, were less considered. Aristotle had supposedly defined their scope once for all and, though occasional men like Leonardo da Vinci were interested in the animal and vegetable life amid which they lived, most men dismissed it from their speculations.

The discovery of America insensibly changed this attitude. Here were adventure, romance, fabulous wealth, strange beasts. Men eagerly sought for details of this Eldorado, and tales spread from learned men and courtiers to the illiterate laborers swapping stories in country inns. Shakespeare, painting the passing show in England, remarked in "The Tempest:"[1]

> Were I but in England now, (as once I was), and had but this fish painted, not a holiday fool there but would give a piece of silver; there would this monster make a man; when they will not give a doit to relieve a lame beggar, they will lay out ten to see a dead Indian.

The first to bring tidings of the New World were Spaniards, following close upon the heels of Christopher Columbus. There was Don Gonzalo Fernandez de Ovieda y Valdes, Spanish Governor of San Domingo in 1517; and the Peruvian missionary, Reverend Joseph d'Acosta, S. J., who was the first white man to discover fossil bones in South America, though he did not recognize their importance to paleontology. There was Francesco Hernandez, a Spanish physician sent to Mexico by King Philip II to report on plants, animals, minerals and men; and Bernal Diaz del Castillo, companion of Cortez, astonished at the marvelous botanical and zoological gardens of Montezuma's splendid courts at Chapultepec; and there was Garcilassa de la Vega, son of a Spanish Governor of Peru and a princess of the royal Inca blood, whose traditional ancestors were Manca Capac and the Sun. This

[1] Written in the year 1611. The island of Bermuda was discovered in 1593 by Henry May, who was shipwrecked there and probably the exploration of those islands gave Shakespeare his setting.

royal half-breed was the first native of the American continents to write of his country and in his "Royal Commentaries of Peru," produced a valuable book, remarkable, like those of many of the early commentators on America, for its freedom from marvel-seeking.

The French were destined to explore the vast western prairies and plains of North America, sending Longueil in 1759 to discover the Big Bone Lick of Kentucky while navigating the Ohio River; to produce Cuvier, who with Buffon was the well-spring of American as well as European natural science when the nineteenth century had just dawned; and to inspire great teachers like Lamarck, Lesson, Audubon and Rafinesque. France had an early interpreter of the Americas in Jean de Lery, a Huguenot missionary to Rio de Janeiro in 1595, but almost two centuries elapsed before the French became the spokesmen of the New World. This interval was occupied by careful English observers in our Eastern States; men like Thomas Harriet, a protegé of Sir Walter Raleigh's; Captain John Smith, of Virginia; and Governor John Winthrop, William Wood and Thomas Morton, of New England. The Dutch, Germans and Swiss played no part as chroniclers of these early explorations.

Two centuries passed, and the little Swiss canton of Neufchâtel took a leading part in American development by yielding to Princeton University Arnold Guyot, comrade of Agassiz in glacial investigation; to our national Geological Survey, Leo Lesquereux, the interpreter of the flora of our vast coal beds; and to all America, Louis Agassiz, glaciologist, zoologist and primarily teacher, whose contagious enthusiasm, profound knowledge and skilful instruction made scientific pursuits dignified, fashionable and valuable in the eyes of the American people.

Agassiz arrived in Massachusetts in 1846, a European scholar of recognized ability and intellectual daring whose reputation rested upon monumental researches into the science of living and fossil fishes and upon his new and, at the time, incredible theory of a glacial age. Science was not a serious vocation for American men, engaged in the business of building up a country. Europe was the center of learning and the mecca of scientific students, as it is to-day of artists and musicians. Tradition and authority rested with the European masters, and Agassiz came with the luster of his tutelage under Cuvier, the brilliant founder of paleontology, and under Baron Humboldt, who had succeeded to the place once occupied by George Leclerc Comte de Buffon, as the dean of scientific men in all Europe. To these great masters he added familiarity with the British geologists of contemporary fame, Buckland, Murchison, Sedgwick and Lyell. He came as a professor, lecturing before the Lowell Institute, and remained as a citizen whose enthusiastic welcome by American institutions was reciprocated by his enthusiasm for American institutions. Having been forced by poverty to copy his reference books, when access to the originals was difficult, and having known the hardships, even hunger, which beset any but the wealthy who sought an education in the Swiss, German and French universities, Agassiz was impressed by the free schools and public libraries of the Commonwealth of Massachusetts. He saw in them his opportunity to teach thousands and he embraced it.

Agassiz's school education had been a nine-hour daily drilling in languages, the classics and arithmetic, overshadowed by the fact that his father's slender clerical income must provide for other children beside himself, and by the grave possibility that unless he showed unusual promise he must at the age of fourteen give up the lessons he loved and go to work for his uncle, who was a merchant. It had given him the moral

force and courage essential for his scientific career which virtually began when he won his parents' permission to enter the little Academy of Lausanne, just before his fourteenth birthday. He entered the academy with an expressed desire to "advance in the sciences" and a plan mapped out in his mind of study at the University of Neufchâtel, to be followed by four years at a German university and to be crowned by work in Paris. This ambitious program worked out surprisingly well.

At Lausanne, Louis received his first lessons in zoology and spent his spare time in the woods and fields, or swimming and fishing in the lake. His desire to "see for myself where the truth is" grew strong and convinced his uncle, Dr. Mathias Mayor, who was a prominent physician of Lausanne, that Louis had a great natural bent for the study of anatomy and, therefore, of medicine. Dr. Mayor persuaded the boy's parents to this view and in 1824 Louis, who was then seventeen, entered the medical school at Zürich. His younger brother, Auguste, remained with him and together the boys copied in longhand books they were too poor to buy—among these was Lamarck's "Animaux sans Vertebres," which was of little interest to the younger brother, yet he faithfully wrote it out for Louis.

In 1826 Auguste entered his uncle's business at Neufchâtel, and Louis went to the University of Heidelberg, to unexpectedly become an author before he had become a doctor of either philosophy or medicine. He arrived at the university with glowing letters from his professors at Zürich, which, with his native charm and apparent determination to work, soon won him recognition. An interested professor suggested that he make the acquaintance of a fellow-student, Alexander Braun, who was as interested in botany as Agassiz was in zoology; thus Agassiz formed one of the greatest friendships of his life and was led into making a momentous change in his university. The boys were constantly together, studying, talking, taking long walks into the country. It being too far for Louis to spend his vacations at home, Braun invited him to his father's house at Carlsruhe where they were encouraged to examine Herr Braun's fine collection of minerals and to pursue their own investigations. In 1827 Agassiz fell ill of typhus fever and the anxious Brauns cared for him at Carlsruhe, Alexander accompanying him to the Agassiz home at Orbe for his convalescence. In October of that year, Braun, whose interest in botany was to bring him distinction in the directorship of the Berlin Botanical Gardens, wrote Agassiz that he considered the University of Munich a better place than Heidelberg for the development of their scientific knowledge. Among the inducements were free lectures, lodgings as cheap as those at Heidelberg, a theater open to students for a very small fee, and the association of such men as Oken,[2] Schubert and Fuchs, as well as a rich museum for study and comparison. Agassiz thought well of the suggestion and the two set out on foot for Munich, followed very shortly by Karl Schimper, one of their firm friends. It was at Munich that Agassiz unexpectedly became an author at the age of twenty-one.

While still keeping up his medical studies out of deference to his father's wishes, he had become more and more enthralled by the natural sciences and in Munich were Martius, Oken, Döllinger and Schelling, men who could teach the eager young man, and who were quick to recognize his worth. C. F. P. Von Martius was at that time engaged in publishing his great work on "The Natural History of Brazil," which he and J. P. Spix had investigated in 1819 and 1820 while touring the country on horseback, in sailboat and canoe. Spix

[2] Transcendental anatomist, author of *Philosophie der Natur.*

undertook the zoological portion of the work, but in 1826 he became ill and died, leaving the description of the fresh-water fish untouched. Martius engaged the nineteen-year-old Agassiz for this task and was well repaid for his belief in the young Swiss, whose doctorate of philosophy predated his first publication just long enough to appear beside his name on the title page of the first edition, in 1829. Agassiz had characterized nine genera, embracing forty-two species new to science. The first copy of the "Brazilian Fishes" went to Cuvier, and Agassiz received a long and gratifying letter in reply. In fact, he was so heartened that he began the composition of his monograph on "The Fresh Water Fishes of Central Europe," for which he had first collected material in the Lake of Morat. He employed an artist, Joseph Dinkel, and secured magnificent illustrations which repaid him for his personal discomfort while eking out a living for himself and Dinkel from his very meager funds. In 1830 he succeeded in interesting a publisher named Cotta, of Stuttgart, in the materials thus far accumulated and secured 20,000 Swiss francs for the work, which appeared subsequently between the years 1839 and 1842.

In 1830 also, when twenty-two years old, Agassiz was awarded the degree of doctor of medicine, with honors, from the University of Munich and proceeded toward Concise to set himself up in medical practice. On the way home he stopped at Vienna to study the fossil ichthyology toward which his investigations of the living forms had directed his attention. Arrived home, however, he seemed to settle down to becoming a practicing physician; this quiescence lasting little more than a year. In December, 1831, Agassiz set out for Paris, finally fulfilling his boyish plans of study through his uncle's generosity, and still but twenty-four years old. He took a small room near the Jardin des Plantes and went on his very first day in Paris to call upon Cuvier. He was warmly received and so won the master's respect and trust that Cuvier turned over material he had collected for a monograph on fossil fishes, which was later incorporated in Agassiz's "Recherches sur les Poissons Fossiles," the appearance of which in 1833 won Agassiz at the age of twenty-six the coveted Wollaston medal of the Geological Society of London. Cuvier did not witness his young friend's triumph; in 1832, only a few months after their first meeting, he had died, leaving Agassiz a well-stocked memory of his views and the admonition "Work kills." Of this maxim the robust Agassiz remained heedless.

The publication of the "Poissons Fossiles" in five volumes illustrated throughout by Joseph Dinkel had been no easy task. After months of a tormenting struggle to make ends meet, Agassiz had finally interested Baron von Humboldt in the work and had thus secured publication funds and the benefit of the Baron's extensive and influential connections. Von Humboldt developed a decided liking for the Swiss student and so in 1832 the chair of natural history at Neufchâtel University was secured for a poor physician who had been wavering on the brink of return to his country practice.

Discovery of the Glacial Age

In 1832 Louis Agassiz was a tall, healthy young professor just starting upon his career at Neufchâtel and planning the formation of a natural science society which took form in December of that year with interesting results, because before this body Agassiz first promulgated, in the year 1837, his theory of a Glacial or Ice Age. Twenty-two years of previous observation by Venetz and Charpentier led up to this great generalization.

In 1815 M. Charpentier, the director of the salt works at Bex and a distin-

guished geologist, had passed a night at a mountaineer's hut in the hamlet of Lourtier and had been told by his host that huge boulders of Alpine granite were frequently found perched on the sides of valleys where they could only have been left by ice. Charpentier became interested in the theory and spent the succeeding twenty years in accumulating evidence that Switzerland had once been covered by a sheet of ice. Agassiz at that time was absorbed in studying fish, living and fossil, and in 1828 his intense observation of the Brazilian fish and the fossil forms of European waters led him into geology through the backdoor of paleontology. In 1834 Charpentier published his conclusions; Agassiz was interested but unconvinced; he visited Charpentier and surveyed the land for himself, becoming more and more enthusiastic about the evidences of the "Ice Age," and in 1837 he boldly declared his belief, that before the elevation of the Alps a sheet of ice had covered Europe from the North Pole to the Mediterrean sea. He was considered mad. The French, German and Swiss scientists, even in his immediate group, laughed him down and were echoed by his English friends of recent acquirement—Buckland, Sedgwick, Murchison and Lyell. However, one by one, they bowed to Agassiz's careful study of the Aar glacier from the Hôtel des Neufchâtelois, which he and his friends, Guyot and Desor, constructed of logs on the living glacier; his calculation of the speed of a glacier's advance; his perilous descent into its heart and consequent knowledge of its actual construction; his examination of the grinding effect of ice upon rocks; his ascent of the hazardous Jungfrau and Matterhorn. Scotland, England and Ireland gave further mute testimony in support of Agassiz and later North America and finally South America bore him out. The scientists capitulated and the glacial age or ages now occupies fifth grade geography books. "It is a matter of the greatest importance to know," wrote Agassiz in 1837, "if toward the Poles and generally wherever erratic boulders exist, the rock surface that carries them is polished as in the Jura." It took a long time measured in a lifetime for him to find out, as Jules Marcou has described from his own memories of the event for the editor of *The Nation:*

The city of Neufchâtel has just celebrated the fiftieth anniversary of the foundation of its Natural History Society. On the sixth of December, 1832, under the leadership of L. Agassiz, a small group of six scientific men met to found this society. Agassiz was then only twenty-five years old. He came from Paris, where he had studied with Cuvier and Humboldt, and the small city of Neufchâtel, which had then scarcely 6,000 inhabitants, by a rare good fortune which does the greatest credit to the liberality and wisdom of its citizens, acquired this young naturalist, full of enthusiasm, of learning far beyond his years, and of a prodigious activity for work for the propagation of science such as few people are gifted with. . .

The orator of the day, Professor Louis Favre, . . . recalled all these works of Agassiz's. . . Especially when the orator spoke of the "glacial theory" did he interest all his hearers. Venetz, of the Valais, had shown the transportation by glaciers of the enormous erratic boulders which lie all along the valley of the Upper Rhone, and first had the idea of the glacier as the conveyor and carrier of these colossal masses. Then his friend de Charpentier, of Bex, pushing the first idea a step forward, extended the glacier of the Rhone over Lake Geneva, over the Canton de Vaud, and stopped it at the Jura. Then Agassiz came in convinced by de Charpentier that the theory of the ancient extension of glaciers and of the transportation of boulders by ice was based on irrefutable observations; he went further, and at a meeting of the Helvetian Society of Natural Sciences at Neufchâtel on July 24, 1837, over which he presided, in his opening speech, he declared "that there had been a time when glaciers covered the whole area of the Alps, and extended far beyond; that there has been in Europe a period of great cold, a great 'Ice Age' when the mammoths lived."

It was a great revolution in science. These words on the existence of a "glacial epoch" raised a tremendous tempest. His adversaries present at the meeting were Leopold von Buch

and Elie de Beaumont, two of the greatest geologists of the first half of this century, and the greatest advocates of the currents of mud and the transportation of erratic blocks by geological floods of prodigious and incalculable force. Endless discussions followed, but the Rubicon was crossed, and it was at Neufchâtel that first dawned the idea of this "Great Glacial Epoch," which little by little, by means of the accumulation of observations in almost all parts of the globe has confirmed the view of the president of the Helvetian Society of Natural Sciences in 1837.

. . . at last Agassiz had the happiness before dying of seeing his theory of a "glacial epoch" accepted by all—even by some of his most constant adversaries, like Sir Roderick Murchison, who wrote to him in 1863 excusing his long opposition. It was but justice. Agassiz by a stroke of genius had seen and seized with a single glance a whole period in the history of the earth—a period till then entirely unknown to all; and, regardless of opposition, he had bravely proclaimed it before the scientific world, certain beforehand that this idea must prevail.

In 1846 a commission from the King of Prussia took Agassiz to America and gave him the opportunity of substantiating his glacial theory, as he had from the beginning expected that an examination of the geology of North America would do. He explored the country for evidences of ice action from the Atlantic Coast to the Rocky Mountains, from the Great Lakes to the Gulf of Mexico, and found erratic blocks, polished and striated rocks, and terminal moraines everywhere north of the thirty-fifth parallel, which forms the northern boundary of South Carolina, Georgia and Mississippi, and cuts into approximate halves Arkansas, Oklahoma, Texas and New Mexico. These phenomena he fully described in his book on Lake Superior. Agassiz was clearly convinced of the universality of the glacial theory and believed that an investigation of the Southern hemisphere would bear him out in this belief. In 1865 a trip to Brazil with his wife and sixteen scientific assistants, financed by Mr. Nathaniel Thayer, of Boston, and Don Pedro, emperor of Brazil, fulfilled his convictions and made more familiar to Agassiz the strange tropic forms which had voiced his first bid for fame.

The journey to Brazil[3] lasted sixteen months and Agassiz came back from Rio de Janeiro and Cairo with renewed enthusiasm and with a firmer hold on his frequently expressed belief in the diversity of the origin of animals and of the human race. The geographical distribution of animals indicated to his mind that distinct zoological provinces are each characterized by peculiar fauna and therefore that animals do not originate from a common center, nor from a single pair. The same theory held true for him in the races of men, which in their natural distribution cover the same ground as the zoological provinces; he believed there to be every reason to suppose that the races originally appeared as nations in the regions they now occupy. There was no room in his hypothesis of special creation and cataclysmic destruction for the modern interpretation of the migrations of animals, peoples and cultures in succeeding geologic epochs. But there was room for speculation and growth in his theory of the classification of forms. A true classification of the multiple forms of life was to be found, in Agassiz's opinion, in an unfolding of the original plan of creation. Not physical causes but the direct intervention of the Creator, he thought, alters or wipes out these forms. With Cuvier and certain of the naturalists and many of the natural philosophers of the eighteenth century,[4] Agassiz believed that nature presents a progression of series from the lowest to the highest types of animal life, culminating in man, but that it is not a uniform progress upward from one type, rather a progress of separate units created as links in a chain, bearing some resemblances but

[3] Described by Mrs. Louis Agassiz in a volume entitled, "A Journey to Brazil."

[4] See Henry Fairfield Osborn, "From the Greeks to Darwin."

not derived from each other. So Agassiz contributed two pillars to evolution, as expressed by Professor Joseph Le Conte:

I think it can be shown that to Agassiz, more than to any other man, is due the credit of having *established the laws of succession of living forms* in the geological history of the earth—laws upon which must rest any true theory of evolution. Also to him, more than to any other man, is due the credit of having *perfected the method* of comparison by the use of which alone biological science has advanced so rapidly in modern times.

Life and Influence in America

We may now return to the last years of Agassiz's life in Europe and his arrival in America. During the struggle to establish the glacial theory, Agassiz was equally engaged in establishing himself as a teacher of zoology, as a master of the lore of Mollusca and Echinoderms as well as fishes. His driving will to learn and to expound, and his habit of collecting living and fossil plants and animals in every available cranny of his house might have made a less sociable man in a recluse who was "just a bit queer." Agassiz was gregarious. He attracted people easily and he loved doing it. He had been born in Motier, a little village in the Canton of Neufchâtel on May 28, 1807, in a little Huguenot parsonage, where his father, Jean Rodolphe Agassiz, was rector. His mother, Rose Mayor Agassiz, was the daughter of a physician of a neighboring village, and had a brother, also a physician and Louis's early benefactor in Neufchâtel. So Agassiz's advent in the university chair of natural history was really a home-coming, he was among friends and quickly made the beginnings of a teaching reputation. He also was married in October, 1833, to Cècile Braun, the sister of his friend, Alexander, and settled down in a small apartment as an apparently permanent fixture. There his three children, Alexander, Pauline and Susan, were born. Mrs. Agassiz possessed decided artistic talent and had been occupied before her marriage by illustrating her brother's books. Zoology proved an equally good medium for her and she made many of the drawings in her husband's monographs of the period, "Monographies d'Echinodermes vivants et fossiles," "Etudes critiques sur les Mollusques du Jura et de la Craie," "Recherches sur les Poissons Fossiles" and "Fossil Fishes of the Old Red Sandstone."

With his natural gift of making people fond of him, Louis Agassiz had won the liking of Charles Bonaparte, Prince of Canino, himself an enthusiastic scientist. Bonaparte had for several years planned a scientific journey to the United States and had persuaded Agassiz to go with him. Baron von Humboldt favored the proposal and obtained for his friend a grant of 15,000 francs from the King of Prussia in order to prolong the journey. To this Sir Charles Lyell added arrangements for a course of lectures on the "Plan of Creation" especially in the animal kingdom, to be delivered by Agassiz before the Lowell Institute of Boston. But in 1846 Bonaparte was unable to make the journey, so Agassiz departed from Switzerland alone, leaving his young son, Alexander, at school in Neufchâtel and his wife and daughters with the Brauns at Carlsruhe.

He arrived in Boston in September, a European of fabulous learning, author of profound books, among them the scientifically discussed "Études sur les Glaciers," a professor from foreign universities, and as he walked upon the platform and started to speak in broken but earnest English, a very charming man. Agassiz in turn was cheered by the deep attention and warm welcome of his audience, whose heterogenous mixture of rich and poor, seated side by side in lottery-won seats, amazed him.

He and his audiences got along beautifully together and after completing his course on the "Plan of Crea-

tion," he undertook one on glaciers, also in Boston, which was equally successful. The year ripened to summer, and Agassiz lived at East Boston in a little house with Count François de Pourtales, E. Desor and Jacques Burkhardt. He made excursions in Massachusetts Bay with Superintendent Bache in the United States Coast Survey steamer, *Bibb*, and longer journeys to visit scientists and strange localities. The following winter he lectured in Boston and other cities, while three events occurring in quick succession bound him to the United States for the remaining twenty-six years of his life.

In February, 1848, the French republic was declared, and republicans arising swiftly in Neufchâtel, which had been a dependency of Prussia, carried the canton into the Swiss confederacy. Louis Agassiz's income from the King of Prussia honorably, but finally, ceased. Mr. Abbott Lawrence fortuitously appeared, inspired by his interest in the Lawrence Scientific School which he had just founded at Harvard, and offered Agassiz the chair of natural history. Agassiz accepted and took up his abode at Cambridge, where he soon had the pleasure of welcoming his countrymen, Arnold Guyot and Leo Lesquereux. His wife died about this time, and Agassiz's European ties, except with his mother and children, were practically broken.

The Harvard professorship gave him freedom in which to develop his method of teaching from nature, and to collect many more of his precious specimens. He began writing and publishing in English, joined the American Association for the Advancement of Science, and very soon sent for his thirteen-year-old son, Alexander; the following year, 1850, his second marriage, with Eizabeth Cabot Cary, a talented Boston woman, and the arrival of his two daughters from Switzerland completed his domestication.

He had become interested in coral reefs during the winter of 1850–1851, while executing a commission of the Coastal Survey to investigate the nature of the Florida keys, reefs and channels with their relation to the hummocks and everglades of the mainland. His report gave the Coastal Survey much valuable information concerning the maintenance of channels, placing of signals and construction of lighthouses, and widened Agassiz's interest in the life of the sea. The following two winters he spent at Charleston, sandwiching a course in the Medical College in between the autumn and spring sessions at Harvard and thereby considerably saving the strength he had taxed during that interval in former years to augment his income by lecture trips. At the close of the first winter he was informed of the award to him of the coveted Cuvier prize for his "Fossil Fishes." During the second winter at Charleston he fell dangerously ill of a fever and upon his recovery resigned his professorship at the medical college. He was then forty-six years old.

Agassiz next tried his skill at the education of girls as well as boys, teaching natural science in a young ladies' academy, conducted by his wife and daughters at Boston from 1853 until 1863. This in addition to his university work and his researches.

A Creator of Museums and Laboratories

In perfecting his method of comparison Agassiz had turned every house in which he had ever lived into a museum. His grandfather had given storeroom to stuffed birds, shells, bottled fishes and snakes, dried plants and old bones for years, until they had finally been housed in the Lyceum at Neufchâtel, valued by their collector at several thousand dollars. There they remained when Agassiz came to America, but his habit of collecting persisted and first the house at East Boston while later, after his second marriage, an old boathouse on the

banks of the Charles River served as storehouse for all the treasures except a live eagle and bear whose subsequent history is obscure. By 1850 the mere preservation from destruction of many of these had become a severe drain upon his income and they were moved again —to a wooden building on the college grounds, where a grant of four hundred dollars a year kept them from harm, provided fire did not kindle in their flimsy shelter and ignite the alcohol in which so many of them reposed. They were secured very shortly as a permanent part of Cambridge by a subscription of twelve thousand dollars raised by friends of Louis Agassiz. He in the meantime collected more specimens, storing them in his Cambridge home and at his summer cottage in Nahant.

But mere accumulation was not Agassiz's goal. He dreamed of a museum where collections would be arranged to show the relation of each part of the animal kingdom to every other, so that it might be a potent means of training teachers of science, of awakening students and of enlightening the general public. In this institution he would have laboratories for special students with abundance of duplicate specimens and all the necessary appliances of research; he would also have a library. He attained his dream. In 1858 Mr. Francis C. Gray, to whom Agassiz had outlined his scheme, died leaving a fund of fifty thousand dollars for the establishment of a Museum of Comparative Zoology. A grant of lands worth one hundred thousand dollars was obtained from the Legislature of the State of Massachusetts, Harvard College gave an ample site for a building, and seventy thousand dollars additional funds were raised by private subscription. The projected building was planned to form three sides of a square, the main structure to be three hundred and sixty-four feet long and the wings two hundred and five feet each. Of this plan a section eighty feet long was built in 1859–60 and the museum opened its collections to the public and its laboratories, presided over by Agassiz, to students. From the beginning a bulletin was published, which showed each year that Agassiz found more than enough to occupy him, yet was always ready to welcome further development of his museum. He worked on during the civil war, confident that the country would come through the storm, watching his students go off to war, eager in his explanation of American affairs to his British correspondents, and in the darkest hour of the war he became a citizen of the United States and helped to found the National Academy of Sciences.

In 1869, shortly after his mother's death, Louis Agassiz collapsed; his brilliant overworked mind refused to maintain its killing pace. He retired to Deerfield, Massachusetts, and rested from all mental labor for almost a year. Then he returned to Cambridge with renewed vigor and in December, 1871, set out, at the invitation of Professor Benjamin Peirce, of the United States Coastal Survey, to cruise from Boston to San Francisco in a deep sea dredger, the U. S. S. *Hassler*. Mrs. Agassiz, Count de Pourtales, Dr. Franz Steidachner, and a young student, J. H. Blake, all of the museum staff, accompanied him. The trip was highly satisfactory and Agassiz was ready upon his home-coming in October, 1872, to undertake a new project his students had evolved in his absence. This was for a summer seashore laboratory, where teachers from schools and colleges could spend their vacations in the study of nature. No means of carrying out this proposal was in sight; Agassiz appealed to the Massachusetts Legislature and received the newspaper publicity due a man whose name was known to practically every school child and to every American teacher of nature study, to captains of fishing smacks and of ocean liners who put to sea carrying

collector's cans for the museum, to the cultivated audiences of lecture courses and to small academies, to geologists and mineralogists and through them to coal operators and iron smelters, from Boston—in cities fired by his personality to an interest in a subject hitherto considered dry and without profit—two months' journey westward to San Francisco and from Maine to New Orleans. Mr. John Anderson, a wealthy tobacco merchant of New York, read the appeal and was moved to offer for the school his island of Penikese, lying at the entrance of Buzzard's Bay, together with a furnished dwelling and barn thereupon. Scarcely had the offer been accepted when Mr. Anderson added an endowment of fifty thousand dollars and so the school was opened in July, 1873, with Louis Agassiz as director, and Burt G. Wilder, of Cornell University, Alpheus S. Packard, of Brown, and Arnold Guyot, of Princeton, as assistant professors. A yacht for deep-sea dredging was presented the school by Mr. Charles G. Galloupe and placed in charge of Count de Pourtales.

All went well, but in the autumn Agassiz was again worked out. He returned to Cambridge in poor health, working with the grimness of exhaustion. In the middle of a December afternoon he went home, complaining of weariness. Eight days later, December 14, 1873, he died. He was buried at Mount Auburn in a grove of Swiss pine trees with a boulder from the Aar glacier as his monument. Agassiz was a pioneer a hewer of rough paths, but he taught accuracy, painstaking even tedious comparison, observation of the actual forces of nature at work and quiescent, even though such study involved physical hazard to the student. To get at the truth and disclose it was his great objective and something of that spirit has impressed itself on the school of scientific research which he founded in the United States. John Greenleaf Whittier, not a scientist himself but a friend of Agassiz, caught a measure of Agassiz's purpose and method in a poem called "The Prayer of Agassiz" written to commemorate the opening of the school at Penikese:

> We have come in search of truth,
> Trying with uncertain key
> Door by door of mystery; . . .
> As with fingers of the blind,
> We are groping here to find
> What the hieroglyphics mean
> Of the Unseen in the seen,
> What the thought which underlies
> Nature's masking and disguise,
> What it is that rides beneath
> Blight and bloom and birth and death.

Agassiz's American Students

"Read nature, not books," said Agassiz, adding "If you study nature in books, when you go out-of-doors you can not find her." Upon this principle of observation he built up his school, a practical institution dealing in reality, which maturing in America at an opportune moment in our national history directly or indirectly brought us our first seashore laboratories, many of our great natural history museums—among them the American Museum of Natural History, the Cambridge Museum of Comparative Zoology and the Peabody Museum of Salem, Massachusetts—as well as countless university departments of natural science and a flourishing group of explorers of the life of the ocean.

Practically every distinguished biologic American of the fifties, sixties and seventies was a friend or student of Agassiz's. The roster is bright with accomplishment, even to-day. A diligent search in the memories of J. Walter Fewkes, of the Smithsonian Institution, and David Starr Jordan, president of Leland Stanford Junior University—two surviving Agassiz students—supplemented by early reports of the Museum of Comparative Zoology, yields, the following great, although incomplete, list:

Alpheus Hyatt, of Cambridge; William H. Brewer, of Yale; A. H. Verrill, of Yale; J. Walter Fewkes, of the National Museum; Ed-

ward S. Morse, of the Salem Peabody Museum; Alexander Agassiz, of Cambridge; H. James Clark, of Cambridge; F. W. Putnam, of the Cambridge Peabody Museum and the American Museum of Natural History; Samuel H. Scudder, of the Harvard Museum; Burt G. Wilder, of Cornell, and William James, the psychologist.

N. S. Shaler, of Harvard; John McCrady, of Sewanee, Tennessee; J. Henry Blake, hydrographer, of Cambridge; Count Pourtales, of Cambridge; Theodore Gill, of the Smithsonian Institution and the Library of Congress; Theodore Lyman, of Cambridge; J. A. Allen, mammalogist and ornithologist of the American Museum of Natural History; William K. Brooks, of the Johns Hopkins; Walter Faxon, of Cambridge; Charles S. Minot, of Boston; C. O. Whitman, of Clark University and the University of Chicago, and David Starr Jordan.

E. A. Birge, of the University of Wisconsin; Samuel Garman, icthyologist of the Cambridge Museum; Alpheus S. Packard, of Brown University; Charles Stimpson, of Chicago University; T. B. Stowell, of the Cortland State Normal School; P. R. Uhler, of the Baltimore Peabody Institute; S. M. Buck, of Cambridge; Harland Ballard, of Lenox Academy; Joseph Bassett Holder, of the American Museum of Natural History; Joseph Trimble Rothrock, of Philadelphia; Sidney I. Smith, of Yale, and Henry A. Ward, of Ward's Natural Science Establishment.

Frederick H. Snow, chancellor of the University of Kansas; W. O. Crosby, of Boston; Ernest Ingersoll, author of scientific books; Orestes St. John, of the Canadian Geological Survey; C. Fred Hartt, of Cornell and Brazil; S. V. R. Thayer, of Boston; Caleb Cook, of the Salem Peabody Museum; Charles Foley, ornithologist of Canada; Henry Wheatland, of Cambridge; William Glen, of Cambridge; William N. Rice, of Middletown, Connecticut, and General Albert Ordway, of Richmond, Virginia.

William H. Niles, of Massachusetts Institute of Technology; Albert S. Bickmore, founder of the American Museum of Natural History; F. A. Sherrif, of Boston; Edwin Norton, entomologist of Farmington, Connecticut; S. R. Jillson, of Judson, Massachusetts; W. J. Beal, of the Lansing (Michigan) Horticultural and Agricultural College; T. P. Chandler, of Cambridge; Richard Bliss, of Cambridge; Samuel Lockwood, archeologist and geologist of Freehold, New Jersey; J. B. Perry, of Cambridge; Francis Sanborn, of Andover, Massachusetts, and occasionally Edward Drinker Cope.

Edward Burgess, of the Normal College of the City of New York; E. T. Cresson, of Philadelphia; C. W. Bennett, of Holyoke; Edwin Bicknell, of the Salem Essex Institute; J. H. Emerton, of Boston; E. P. Austin, of Cambridge; E. C. Howe, of Yonkers, New York, and Horace Mann's sons, Benjamin P. and Horace.

The Museum of Comparative Zoology at Harvard University opened its doors under a grant secured by Agassiz from the Massachusetts Legislature and with the additional financial support of Mr. Francis C. Gray, of Boston, in 1859. Nineteen students of the Harvard classes in zoology at the Lawrence Scientific School were enrolled as students and assistants. This number had increased by 1872 to one hundred and three, but the civil war intervening in 1861 had called many of the young men to the armies of both North and South. The early museum reports consequently contain incomplete references to men, later lost sight of or occasionally accounted for in such notes as: Craigin, died in the army of fever. Other names without subsequent clues of identity are: Hansen, M. Gugenheim, Edward King, N. Bowditch, C. A. Shurtleff, J. H. Fowler, John Bartlett, S. C. Martin, Louis Cabot, A. R. Crandall, J. Boll (a young Swiss), Wing and W. J. Hubbard.

The encouragement of women students bears witness of Agassiz's open-minded attitude toward the world and education. A number of young women worked in the library and in the preparation departments, cleaning and mounting fossil bones and shells, classifying and arranging exhibits. Undoubtedly their maiden aunts decried the evil influence of the civil war on the younger generation, but the fact that they did a good job stands in the museum records amid frequent references to Miss Slack, the librarian; Miss Annie Cutler, and the Misses Atkinson, Harris, Clark and Cook.[5]

[5] Miss Susan K. Cook was later in charge of the senior grade at the Packer Collegiate Institute, and made a very good record as a science teacher there.

Each of these students imbibed something of Agassiz's method of teaching from observation rather than by rote, from his impatience with the old rock-bound college curriculum of classical learning whether it suited the individual or not, and his consequent championing of the elective system, and from his firm belief:

> *It can not be too soon understood that science is one; and that, whether we investigate language, philosophy, theology, history or physics, we are dealing with the same problem, culminating in the knowledge of ourselves.*

Agassiz like his contemporaries who enjoyed his influence, Samuel Dana of Boston, J. S. Newberry of Columbia University, Arnold Guyot of Princeton and Joseph Leidy of Philadelphia, did not welcome the invading theories of Charles Darwin. But Agassiz, Newberry and Leidy paved the way in their students' minds for a conception of evolution as far-reaching as any Darwin advanced. Agassiz in his titanic researches of ancient and present-day life of the sea, lake and stream, through the vistas of geologic time in his glaciation theory, and in his insistence upon direct observation of nature supplanted the provincial by the universal conception of Creation in his students' minds and gave time and space to a previously finite world.

BIBLIOGRAPHY: "Pioneer of Science in America," by William Jay Youmans, M.D.; "Louis Agassiz, His Life and Work," by Charles Frederick Holdero, LL.D.; "The Services of Louis Agassiz to Cornell University and to Science, Addresses at the Unveiling of a Tablet," June 17, 1885, by J. S. Newberry, of Columbia College; Burt G. Wilder, of Cornell University, and Professors T. P. Stowell and P. R. Uhler; "Encyclopedia Britannica," vol. pp. 367–68; "Alexander Agassiz," by G. R. Agassiz; Reports of the Museum of Comparative Zoology, 1859–1875.

CONTINUOUS FOREST PRODUCTION AS A SOLUTION OF AMERICAN FOREST PROBLEMS

By Professor A. B. RECKNAGEL
CORNELL UNIVERSITY

LAST summer David T. Mason, forest engineer of Portland, Oregon, appeared before the directors of the National Lumber Manufacturers' Association with a remedy for the over-production and consequent depression of the lumber industry. In brief, Mason's proposal[1] is that to meet the net annual depletion of thirty-seven billion feet of softwood timber, which will exhaust our virgin supplies in thirty-seven years, we must stimulate production—not of lumber but of growing forests. He sums up:

> Reasonable changes in government policy, together with the earnest study of possibilities by the principal private timberland owners, will result in the wide introduction of sustained yield forest management, which will solve the problem of American timber supply, the problem of communities dependent upon the forest industries, and will bring prosperity to the forest industries.

This is a "large order." What is sustained yield that it can work such miracles? It is, in brief, to harvest only the amount of timber which is replaced by current growth. The term "continuous forest production" is less technical and carries the meaning better of *keeping the forests productive.*

At present this growth (for softwoods) is only six billion feet annually, as against a depletion of forty-three billion feet annually (of softwoods). At first glance this seems like a hopeless proposition, but an analysis by regions points the way to bring it to pass.

Eastern United States (east of the Rockies): Here the cut is declining rapidly. The net annual depletion is seventeen billion feet. At the end of ten years, lessened cut and more forestry practice will reduce this net annual depletion to eight billion feet. By 1946 regrowth and lessened cut should balance, so that with a harvest of seven billion feet yearly there would be no further depletion—in other words, *sustained yield* would have been accomplished for the softwoods.

Rocky Mountains: Largely in public ownership, the timber in this region is increasingly managed for sustained yield, so that the present net annual depletion of two and one half billion feet will disappear and the cut be stabilized at what the forests can continuously produce.

Pacific Coast States: The three states —Washington, Oregon and California —together with parts of Idaho and Montana, present the nub of the difficulty. Here are the figures:

Present cut	18	billion	feet
Present timber stand	1,080	"	"
Annual cut on sustained yield	16½	"	"
Net change (decrease in cut)	1½	"	"

The greatest decrease would have to be in northwest Washington, the greatest increase in southwest Oregon. How can this be brought about? Mason answers:

[1] *Journal of Forestry*, October, 1927, reprinted in the Commonwealth Review of the University of Oregon, October, 1927. See also reports in current issues of lumber trade journals.

It is not expected that everyone, or even a majority, will adopt sustained yield; but with government cooperation it is believed that a sufficient number of important producers, who find it economically practicable, will within a few years voluntarily adopt sustained yield and will thereby effectively apply the brakes to production.

Sustained yield is making advances in the Southern states where the reserve supply, in the form of second growth, is not so heavy a financial load as in the west. Action of private owners by themselves in this direction in the west is harder because of the relatively large amounts of old growth timber as compared with second growth. Therefore, in the west especially there is great need for public cooperation in carrying the timber burden. The solution of the problem in the critical Pacific Coast states will help enormously everywhere. A solution in the west becomes constantly more practicable as cutting reduces the proportion of private timber to the publicly owned timber, provided the public is willing to cooperate with its timber.

Mason concludes that the future market demand of thirty-seven billion feet of softwood yearly will be met, on a sustained yield basis, as follows:

Eastern states	10	billion	feet
Rocky Mountain states	2	"	"
Pacific Coast states	14	"	"
Alaska	1	"	"
Total	27	"	"

Deficit of production ten billion feet, to be met chiefly by closer utilization and by materials other than wood.

Mason's proposal has engendered much discussion. It is not to be lightly discarded as theoretical and impractical. Colonel Greeley, chief of the U. S. Forest Service, in his annual report for 1927, says we must "recognize that the general reorganization of our forest industries around the sustained yield conception is necessary, that its accomplishment is the great goal to be sought."

He goes on:

Sustained yield is, of course, the underlying idea and essential aim of all forestry. We shall not have solved our national problem until the country as a whole is on a sustained-yield basis, with timber production balancing current use. To the individual lumber or paper or other forest industry the sustained-yield conception offers the most rational basis for stabilizing an enterprise throughout. If the forest industries of the west, where large quantities of virgin timber are still available, could forthwith be placed on a sustained-yield basis, the current output of forest products would not be materially curtailed but expansion would be held down, overproduction would be cured at its source, and a rational stability would be introduced into all phases of industrial planning.

Gains in Private Forestry Practice

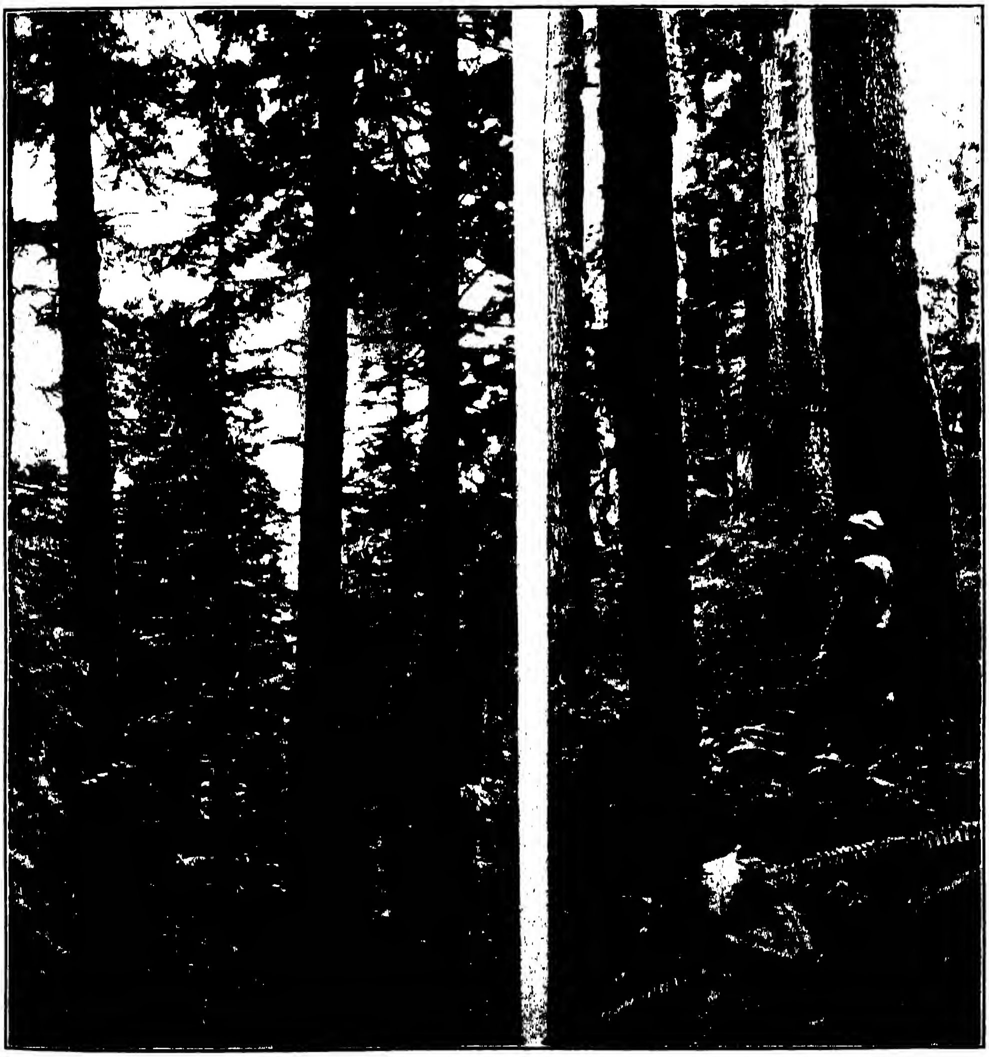
There are 242 million acres of forest land in industrial ownership. On only one tenth of this area is there, to date, some practice of forestry[2]—equally divided, by area, between the North Atlantic, the southern and the western states. Lumber companies, however, practicing some form of forestry make up *only* three fifths of the area on which forestry is practiced.

The reports submitted at the Commercial Forestry Conference in Chicago in November last, show an effort on the part of owners to facilitate the establishment of a second timber crop. This is, in itself, highly commendable, and it is the first step towards sustained yield or continuous forest production.

Further analysis, however, shows that the situation is not so rosy. As long as the virgin supplies last (especially with present stimulation of over-production) it is not likely that sustained yield management will receive serious attention. A few far-seeing lumbermen may do so, but they will be in the minority. The economic processes now in full swing will continue unchecked as far as present indications go.

When the virgin timber is gone, recourse must be had to second growth. It is over-optimistic to think that our wood requirements can be met from this

[2] See "Progress in Commercial Forestry," Chamber of Commerce of the United States, Washington, 1927.



(*Photos by C. P. Cronk*)

VIEWS IN THE IMMENSE TIMBER STANDS, WEST SLOPE OF THE CASCADES.

source when less than two thirds of the cut-over land is restocking at all and the remainder is practically denuded.

Facing the situation squarely, it seems evident that the output of sawtimber raised *as a crop* will fall far short of our future needs. It is the economic factors —over-production, over-taxation and the forest fire menace—that work to prevent lumbermen from practicing continuous forest production. When an official in Oregon writes: "On the average, the owner will lose less by giving his land to the state now than he will if he finances the growing of a new crop under the general property tax," it is indeed high time to inquire into the tax situation on the Pacific Coast. Fortunately, Oregon has been selected by the National Tax Inquiry for its work in 1928.

The Horns of the Dilemma

The lumber industry, much bedevilled by competition within and without, must apparently choose one of two horns of the far-famed dilemma. One horn is to do nothing—"laissez faire" as the French say—"let her ride" in good American. This is the easiest course and is predicated on the supposition that American inventive genius will find some material to take the place of lumber when our virgin sources of supply are gone. This view is seriously held by many of our citizens and may explain, in part, the apathy which has overtaken the conservation movement. It is undoubtedly true that we live in an age of miracles, but it will require a super-miracle of invention to replace the myriad uses of lumber in an industrial country, such as ours.

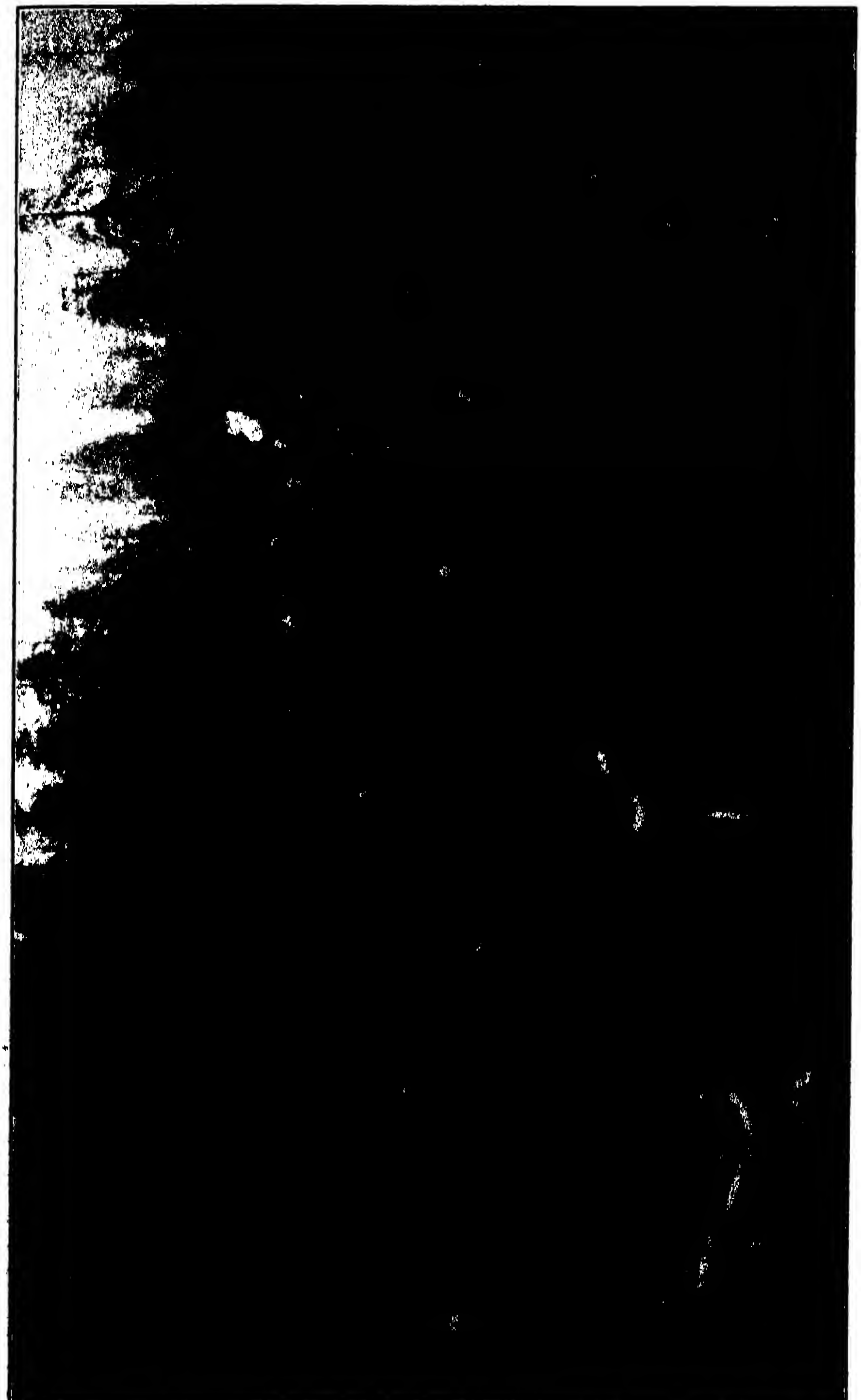
The other horn of the dilemma presents a solution which is typical of modern industry—it is to organize for timber growing. There is nothing new in this concept. The timberland owners of the various German states have been organized for years into associations for mutual help and betterment of conditions. They head up in a national association of timberland owners, which is recognized by the central government in choosing the national forest council.

In the United States we are well accustomed to both regional and national organizations among lumber manufacturers, lumber wholesalers and lumber retailers. These organizations are functioning admirably in the improvement of the industry, notably in trade extension under the National Lumber Manufacturers' Association. But so far all the emphasis has been laid on the *merchandizing* of lumber and little or none on the *growing* of lumber. It is true that certain of the associations have widened their scope to include forestry, but it is as an appendage—a "hors d'oeuvre"—rather than as a principal object.

If Colonel Greeley and Mason and the rest of the foresters are right, if the lumbermen who spoke at the Commercial Forestry Conference in Chicago are right, then the time is ripe for a National Organization of Timberland Owners which shall have as its principal function the development of the timber resources on a basis of continuous forest production.

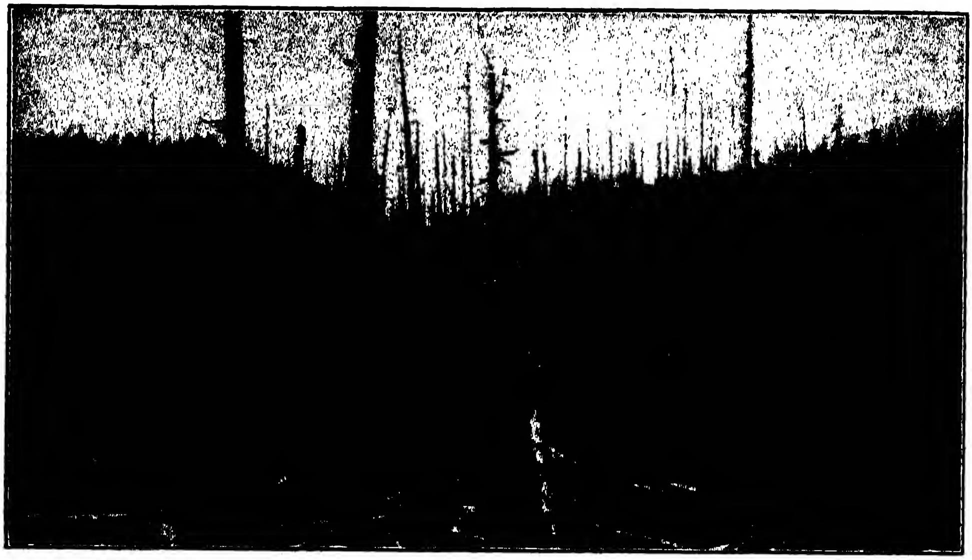
It may be urged that there exists such a multiplicity of associations that any addition thereto is unwarranted. If that be granted, then avoid another association by forming a *National Council of Timberland Owners* (or a "Central Committee of Timberland Owners") whose members shall be representatives of existing organizations like the following:

National Lumber Manufacturers' Association.
American Paper and Pulp Association.
American Railway Association.
Forest Service, U. S. Dept. of Agriculture.
Indian Service, U. S. Dept. of the Interior.



DIFFICULT TOPOGRAPHY OFTEN ENCOUNTERED IN LOGGING RAILROAD CONSTRUCTION IN WESTERN OREGON.

(*Photo by C. P. Cronk*)



(Photo by C. P. Cronk)

FIRE AFTER LOGGING—THE BANE OF WESTERN TIMBER LANDS.

Organizing for Timber Production

Whatever form of organization is favored, the important thing is to organize forthwith for timber production. There is no time to lose. Mason gives thirty-seven years as the outside figure for softwood supplies—others, less conservative, make it thirty years. Not that there will be a timber famine in thirty years—that idea has long since been discarded—but a time of acute depletion of mature growing timber and a consequent attrition of the forest industries.

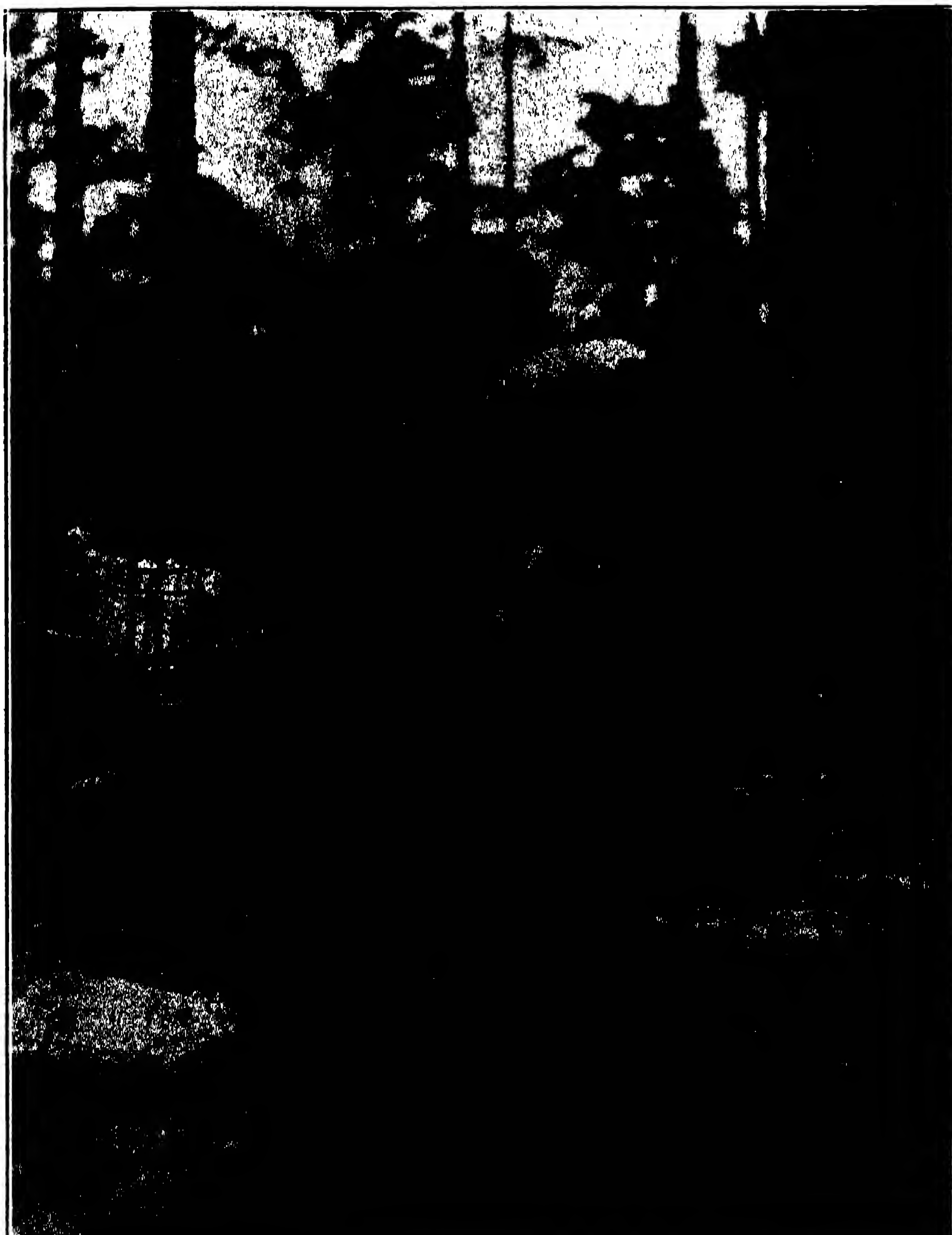
A Program of Work

The National Council of Timberland Owners would address itself primarily to the pressing problems that beset timber growing. What these are is too well known to require repetition. Overproduction, taxes, protection from fire, from insects, from fungi, more technical knowledge of how to grow and harvest forest crops—and many more that might be listed—are problems which baffle the individual but yield to united effort. As the late Bolling Arthur Johnson put it, "Cooperation, not competition, is the life of trade."

Foresters should contribute the best technical skill their profession affords in helping owners of timberland achieve continuous production. There are aspects of forest organization and of forest finance with which the lumberman is not generally familiar that might prove very helpful in solving his particular problem. Mason has put this very well:[3]

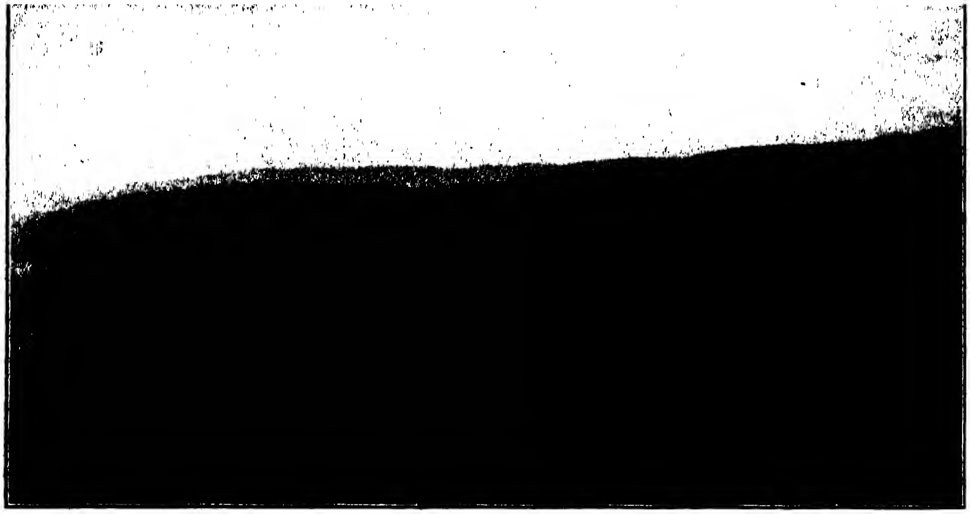
> The first step toward sustained yield on the part of any forest owner is an earnest, intelligent and thorough study of the possibilities of sustained yield in general and as applied to his own individual situation. A mere superficial and perhaps prejudiced guess on the subject will accomplish nothing—indeed, such action is postively harmful; it is necessary to get the basic facts and interpret them intelligently. To be effective the investigation must be made by some one thoroughly competent to do the work. This is no more a job for anyone inexperienced in this particular field of work than would be the designing of a battleship, the planning of a military campaign, or the conduct of an important surgical operation.

[3] *Ibid.*, p. 39.



(*Photo by U. S. Forest Service*)

OPERATING LONGLEAF PINE FOR TURPENTINE IN THE FLORIDA NATIONAL FOREST.



(*Photo by T. Colby*)

LOGGING THE SOFT WOODS ONLY DOES NOT APPRECIABLY BREAK THE CROWN COVER IN MIXED FORESTS OF THE ADIRONDACKS.

Conclusion

If what has gone before is an indication of what is to follow, the American lumber industry—yes, the American people, are on the threshold of an important decision. To go on as we have been, using up our remaining resources of virgin stumpage in a final burst of profitless over-production, is to end up at the blank wall of such scanty and comparatively valueless second growth as chance may have produced.

If, on the other hand, the timberland owners organize now, "take arms against a sea of troubles, and by opposing end them," there should follow a period of stability in the forest industries which has not been known before.

The ills of the lumber industry can be cured only at the source, and the source is the timberland. Assured of continuous production of timber in amounts adequate to meet the country's future needs, the present top-heavy enterprise would readjust its processes of manufacturing and marketing with profit to the industry, to the consumer and to the country as a whole. Is not this goal worth the best effort of all lumbermen? Is it not time that the forest land owners who "recognize the national necessity of continuous productivity of their lands when economically feasible" follow the recommendations of the National Conference on Commercial Forestry, and "recognizing their responsibility, assume as a civic duty the leadership in this great national business enterprise, already well begun?"[4]

[4] Quotations from Resolutions adopted at the Commercial Forestry Conference in Chicago, November, 1927.

THE PROGRESS OF SCIENCE

THE FOURTH INTERNATIONAL CONGRESS OF ENTOMOLOGY

By Professor Glenn W. Herrick
CORNELL UNIVERSITY

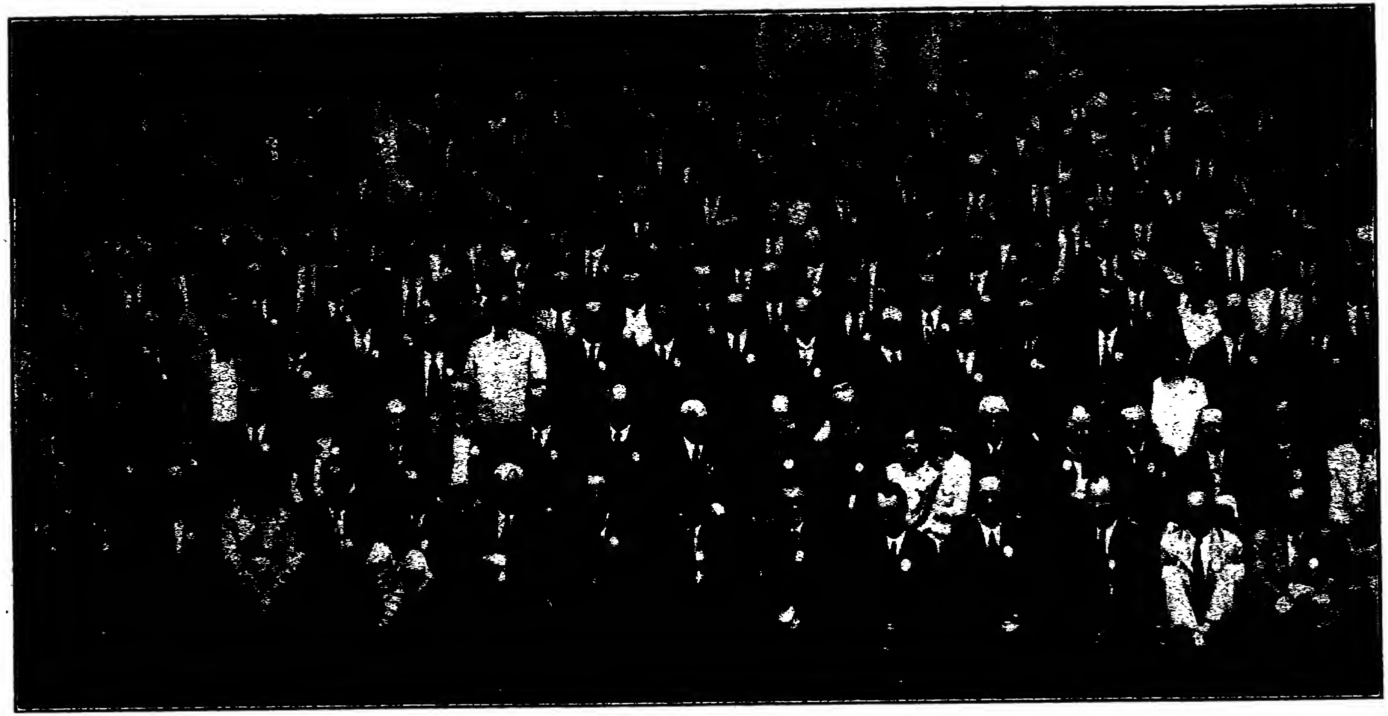
The Fourth International Congress of Entomology held at Ithaca from August 12 to 18, inclusive, proved to be the most largely attended entomological congress yet held. The total number registering was 515 active members and 110 associate members. Of these, 123 active and 12 associate members, were foreigners representing 38 countries, thus imparting to the congress a truly international tone which was particularly gratifying to all of us who had participated in the organization of the week's activities.

The first contingent of foreign entomologists, headed by Dr. Karl Jordan secretary of the permanent executive committee, arrived in Ithaca on Saturday, August 11. Early on Sunday morning, August 12, a second group of Europeans arrived and the activities of the congress began in earnest, as two excursions for those interested in collecting had been arranged.

The headquarters and place of registration were located in Willard Straight Memorial Hall, the social center of the students of the university when it is in session, which proved to be almost an ideal building for the purpose. The meetings for the reading of papers and discussions were held mainly in the Baker Laboratory of Chemistry with an overflow of two sections into the Rockefeller Hall of Physics just across the way. Baker Hall, with its main assembly room in which the general sessions were held and its numerous lecture rooms with lanterns, proved convenient for bringing the meetings into a compact area.

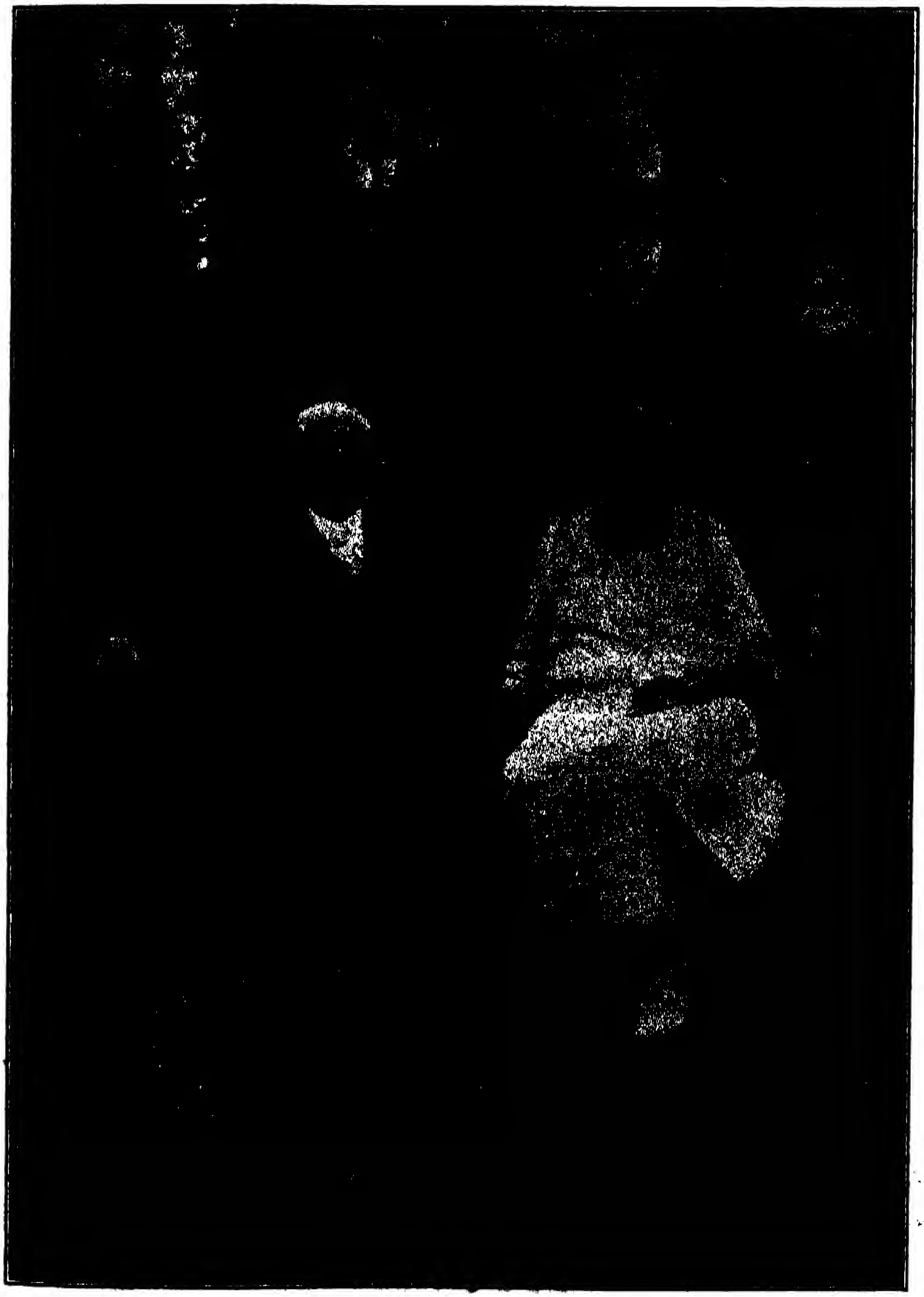
On Monday morning the congress opened with a general session in Bailey Hall. By this time over five hundred visiting entomologists had registered who, together with their wives and the local visitors, formed an impressive gathering. Brief and happy addresses of welcome were given by Dean W. A. Hammond, of the university faculty, and Dean A. R. Mann, of the New York State College of Agriculture. These were followed by the address of the president of the congress, Dr. L. O. Howard, who presided in his ever happy and delightful manner. In his address Dr. Howard stressed the importance of entomology in the economy of human activities and urged that more time be given in the courses of zoology in the universities of this country to the teaching of entomology. He gave a fine tribute to Professor John Henry Comstock, who began the teaching of entomology at Cornell as a distinct subject in 1871 and who developed it to its appropriate rank among other zoological subjects through his continuous labors extending over a period of more than forty years. The address of Dr. Howard appears in full in *Science* in the issue of August 17. Following the address of the president, three papers were read by Dr. René G. Jeannel, of France; Dr. Karl Jordan, of England, and Dr. Ivar Trägårdh, of Sweden. Dr. Jordan then gave a brief report as secretary of the permanent executive committee.

Four general sessions were held at which papers dealing with the broader aspects of entomology were read by representative men from foreign countries and from America. During the afternoons the sections on the various divisions of the science held their sessions. In general, only four or five papers were scheduled for each of these afternoon sessions, thus giving every one an opportunity to return to Willard



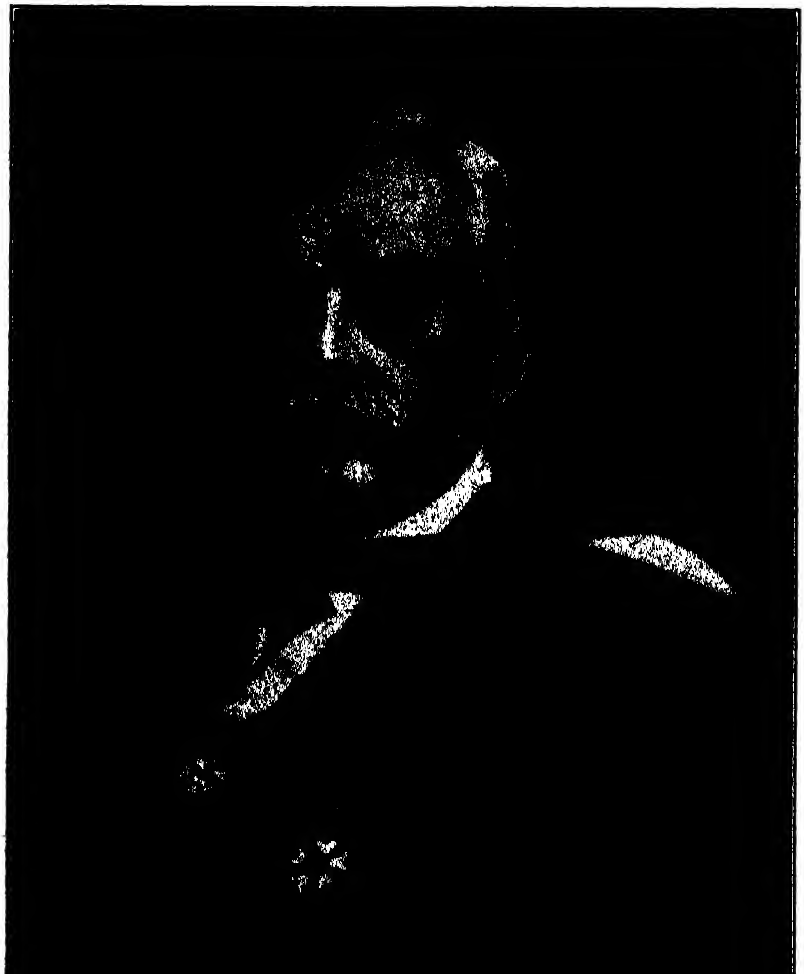
ENTOMOLOGISTS OF THE WORLD AT CORNELL UNIVERSITY

In the middle, marked by a small cross on the badge, is Dr. L. O. Howard, president of the congress, surrounded by a group of eminent foreign and American entomologists. At Dr. Howard's left (the reader's right) is Dr. Karl Jordan, of England; next to him is Professor E. L. Bouvier, of France. At Dr. Howard's right is Dr. Filipo Silvestri, of Italy; next to him is Professor W. M. Wheeler, of Harvard University. Sitting in front of Professor Wheeler is Dr. W. J. Holland, at whose left is M. Cameron, of England, and next to him Dr. J. P. Kryger, of Denmark. Standing between Dr. Jordan and Professor Bouvier is Dr. James Waterston, of England. On his right are D. D. de Torres and G. Ceballos, of Spain.



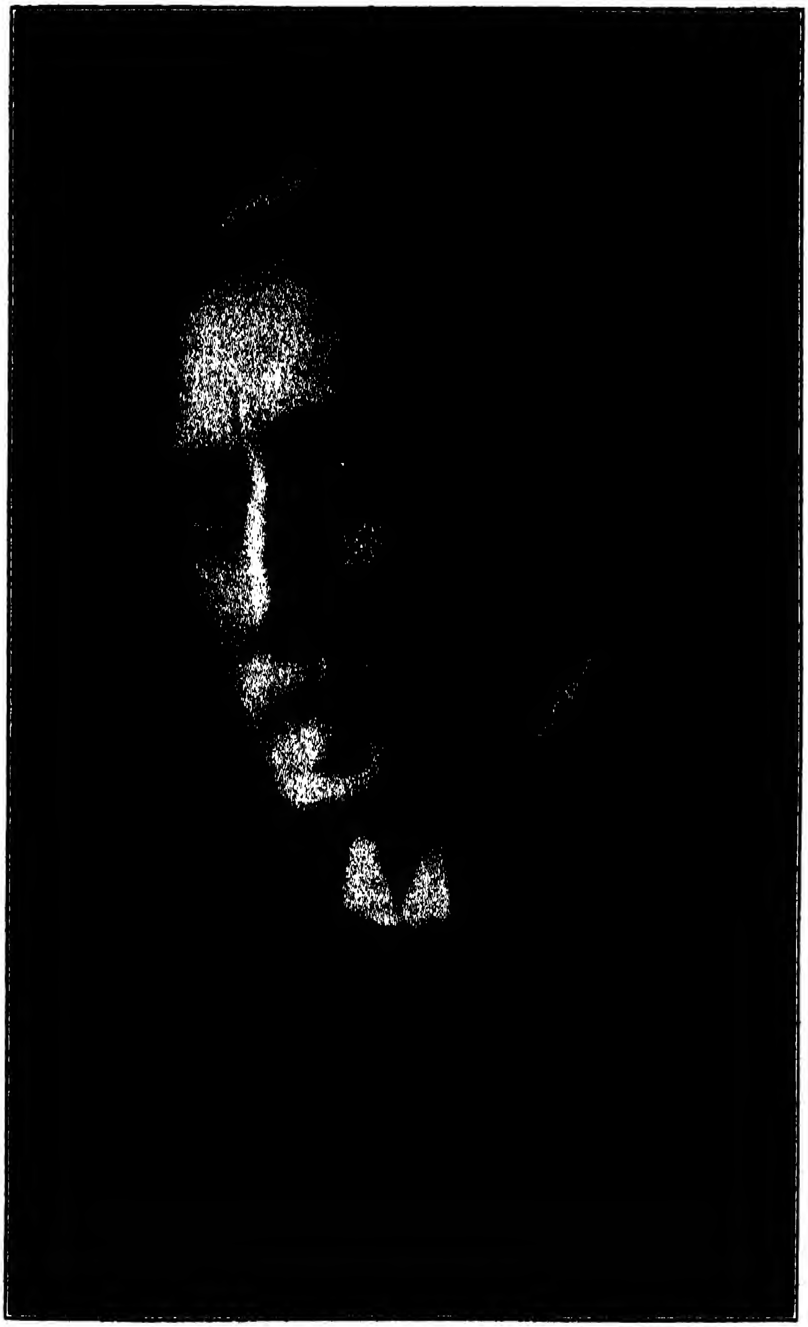
PROFESSOR J. H. COMSTOCK AND MRS. COMSTOCK

PROFESSOR COMSTOCK, NOW IN HIS EIGHTIETH YEAR, INSTRUCTOR AND PROFESSOR AT CORNELL SINCE 1874, WAS ABLE TO WELCOME THE CONGRESS TO THE UNIVERSITY WHICH LARGELY THROUGH HIS INFLUENCE HAS BECOME THE CHIEF CENTER OF ENTOMOLOGY IN AMERICA. MRS. COMSTOCK, ALSO NOW PROFESSOR EMERITUS, IS DISTINGUISHED FOR HER CONTRIBUTIONS TO NATURE STUDY.



DR. W. J. HOLLAND

EMERITUS DIRECTOR OF THE CARNEGIE MUSEUM AND FORMERLY CHANCELLOR OF THE UNIVERSITY OF PITTSBURGH, WHO WAS MADE AN HONORARY MEMBER OF THE CONGRESS ON THE OCCASION OF HIS EIGHTIETH BIRTHDAY.



PROFESSOR STEPHEN A. FORBES

CHIEF OF THE ILLINOIS NATURAL HISTORY SURVEY, LONG PROFESSOR IN THE UNIVERSITY OF ILLINOIS AND STATE ENTOMOLOGIST, NOW IN HIS EIGHTY-FOURTH YEAR, WHO, LIKE DR. HOLLAND, TOOK AN ACTIVE PART IN THE CONGRESS AND WAS ALSO MADE AN HONORARY MEMBER. WITH DR. COMSTOCK, THEY ARE THE ONLY LIVING AMERICANS WHO HAVE RECEIVED THIS HONOR.

Straight Hall for tea and other social activities.

On Wednesday, the congress moved to the New York Agricultural Experiment Station at Geneva, New York, where the sections on systematic entomology and zoogeography and economic entomology had their meetings in the afternoon, but no general session was held. Instead, during the forenoon, the New York State Horticultural Society with its hundreds of progressive fruit-growers held its meeting, at which Mr. Thomas B. Byrd, of Virginia, gave the principal address. This meeting of the Horticultural Society gave the visiting entomologists an opportunity to see a representative body of fruit-growers and farmers of America. In addition, the U. S. Department of Agriculture, under the direction of L. H. Worthley and R. B. Gray, gave a demonstration of the measures in operation for the control of the European corn borer.

The congress was notable for the large number of foreign entomologists in attendance. For the first time, we American entomologists had an opportunity of meeting in a body our foreign confrères, of talking over with them our mutual problems, and of getting acquainted with them in a social way. It was a wholesome, delightful and memorable experience.

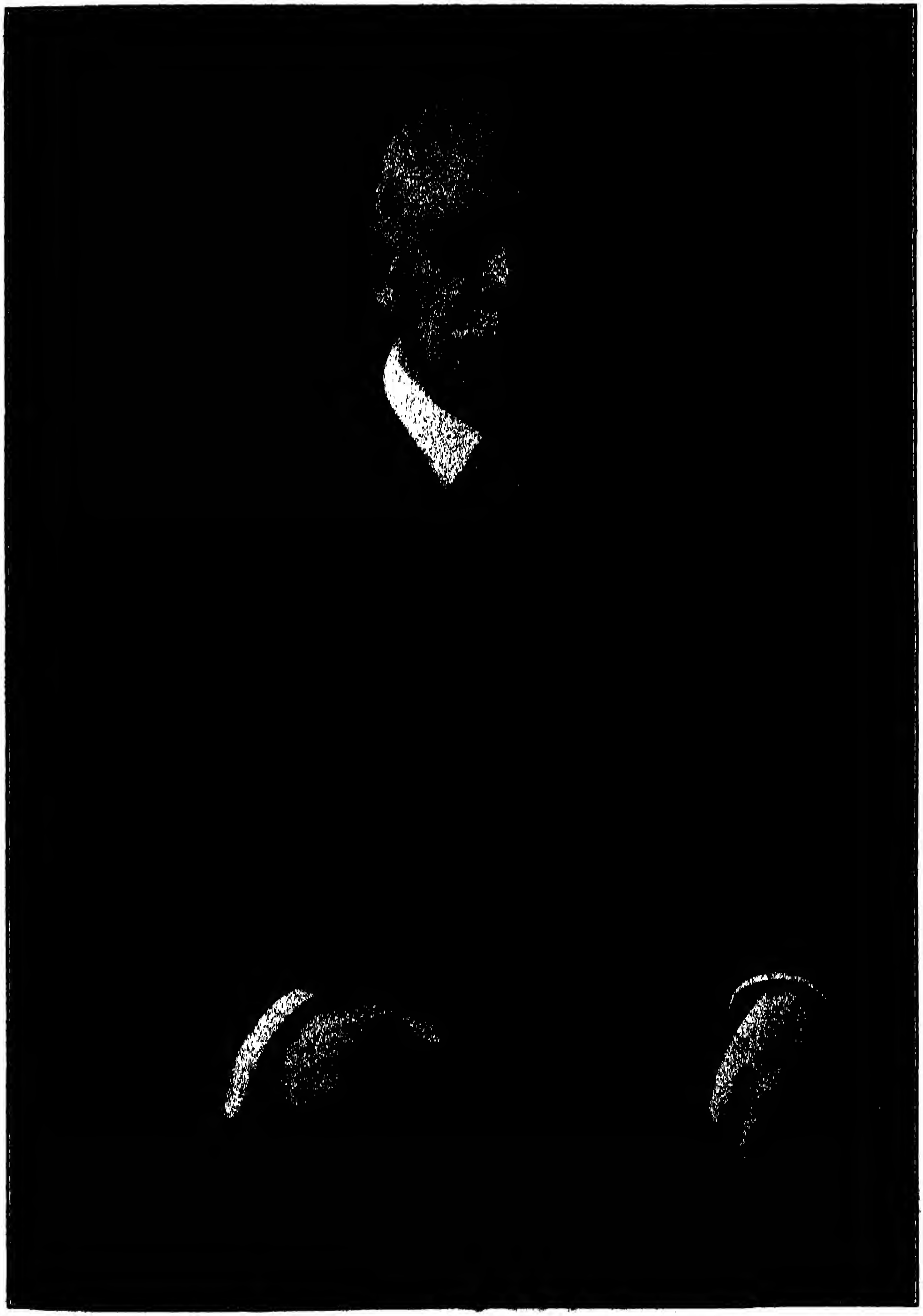
In all about 175 papers dealing with all phases of entomology were read. For the first time, three separate sections devoted to papers dealing with forest insects were organized. The attendance at these sections was unexpectedly large and the interest shown in the papers warrants a continuance of them.

Each of the previous congresses at some time during its meeting has been in the habit of conferring distinction upon certain eminent entomologists by electing them "honorary members of the congresses." In all fourteen individuals have been thus honored. Of these Professor John Henry Comstock, of Ithaca, was the only living American representative. It was therefore fitting that the present congress should follow the action of previous ones in honoring certain eminent entomologists. This the congress did by electing Dr. W. J. Holland, of Pittsburgh, Pa., and Dr. Stephen A. Forbes, of Urbana, Illinois, "honorary members of the congress."

The banquet, which was the concluding social event of the congress, was held on Friday evening, August 17, in the large hall of Willard Straight. Dr. Howard, in the capacity of toastmaster, called upon representatives from thirty-one countries, each of which arose and spoke a few words in his native tongue. At least fifteen languages were spoken in the responses by the different members. In this respect the banquet was unique.

The next International Congress of Entomology will be held in Paris in 1932. It is hoped that a large number of entomologists from Canada and the United States may return the visits of the Europeans and thus renew and continue the acquaintances formed here during the fourth congress. We believe that these opportunities for the coworkers of different nationalities to become acquainted with each other will contribute much toward more friendly intercourse among the scientific men of the various countries represented, and that they will certainly exert their influence toward a more mutual respect between the peoples of the different nations involved.

The effects of the human contacts made during the week at Ithaca, of the intellectual stimulus produced by the exchange of ideas and of the renewed realization that investigators of other countries possess the same human sympathies, desires, wholesome ambitions and sincere devotion to truth as oneself, live on in the mind of every one of us and will continue to exert a widening influence toward a broader respect, tolerance and charity for each other's personality, work and aims.



DR. ARTHUR D. LITTLE

THE DISTINGUISHED ENGINEERING CHEMIST, OF BOSTON, WHO WAS ELECTED PRESIDENT OF THE SOCIETY OF CHEMICAL INDUSTRY AT ITS RECENT NEW YORK MEETING TO PRESIDE AT THE MEETING TO BE HELD NEXT YEAR AT MANCHESTER.

THE BIOLOGICAL EFFECTS OF X-RAYS

Dr. Charles Packard, of the Institute for Cancer Research at Columbia University, has been successful in finding a method by which the biological action of Roentgen and radium radiations can be determined quantitatively. Radiologists have long sought some sort of cell or tissue showing an easily recognized change which varies with the dosage. Among the various kinds of cells which have been tested, the eggs of Drosophila are undoubtedly the best.

Dr. Packard's method consists in radiating some hundreds of eggs, none more than two hours old, and then observing the percentage which hatch out as larvae about two days later. A definite dose kills a definite proportion, which varies in repeated tests within narrow limits. It is seldom that the results of a single test will vary as much as 5 per cent. from the average of all. No other biological material gives results as consistent as those obtained with Drosophila eggs, or which can be repeated at any time.

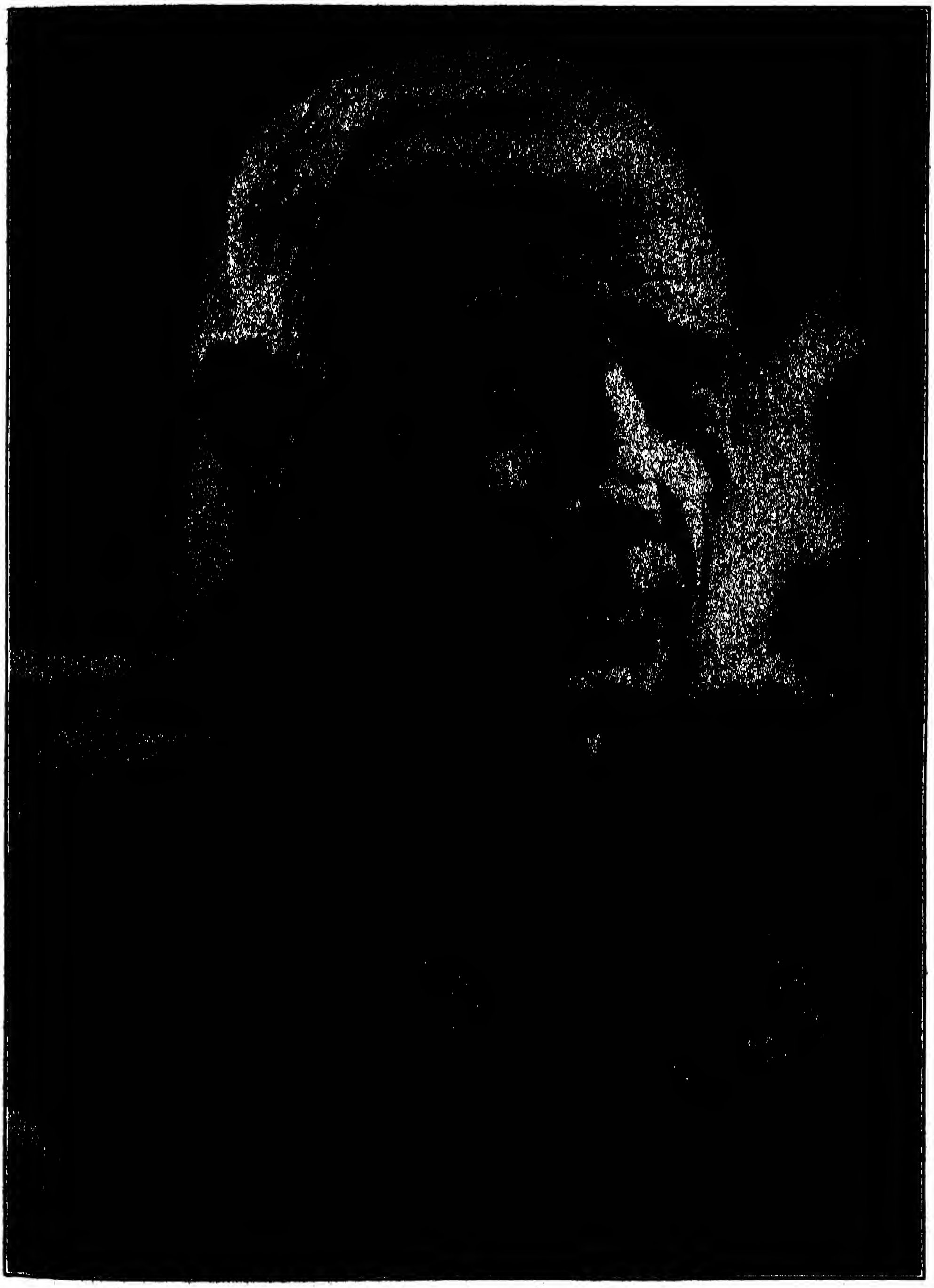
We have here a means for attacking some problems which have long been a subject of debate. Perhaps the most important is that of the biological action of X-ray beams of different wavelengths. This is a practical matter for radiologists because they must treat deep-seated diseases with short, penetrating rays, and superficial difficulties with longer, less penetrating beams. If beams of these two qualities have the same intensity will the biological effect be the same or different in the cells which absorb most of the energy?

The experiments with Drosophila eggs appear to answer this question. When the eggs are exposed to homogeneous beams of widely differing wave-lengths and of equal intensity they are killed at precisely the same rate. This is true also for heterogeneous beams. The results of these experiments, involving more than 30,000 eggs, render highly probable the conclusion that the death rate of radiated cells depends only on the intensity of the beam to which they are exposed and the length of exposure.

These two factors, intensity and time, when multiplied together, give the number of Röntgen units which have been given. Since the death rate varies with these factors, it is obvious that it varies also with the number of Röntgen units. Many experiments show that half the eggs are killed by 180 of these units. This fact makes possible the measurement of the intensities of the beams. They are found to agree remarkably well with measurements by the ionization method. In one test, the results of radiating the eggs showed that the beam had an intensity of 0.260 electrostatic units per second. The physical measurement showed it to be 0.262 electrostatic units per second.

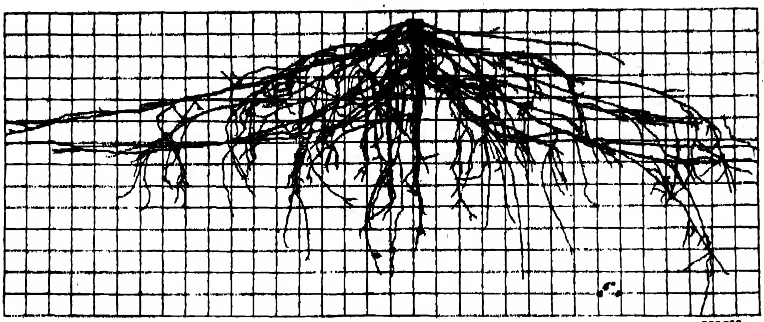
The method is of practical value, for it permits the radiologist to determine the output of his machines with considerable accuracy without the use of the rather temperamental galvanometer and ionization chamber. Many times when the meters indicate that a definite dose is being given, careful measurement shows that the actual output is quite different. The method is already being used to good effect.

One more problem has been attacked in this way. The direct comparison of X-ray and gamma ray intensities, in terms of Röntgen units, can not now be made by physical instruments, because the ionization chamber which will properly measure the X-ray beam is not sensitive enough to detect the very weak gamma radiation. Dr. Packard believes that Drosophila eggs make the comparison possible. A few tests with the gamma rays of measured intensity will show how long an exposure is required to kill half the eggs.



ROALD AMUNDSEN

THE DISTINGUISHED NORWEGIAN EXPLORER OF THE ARCTIC AND THE ANTARCTIC, WHO LOST HIS LIFE IN THE SEARCH FOR THE ILL-FATED *Italia*.



THE ROOT SYSTEM OF A LONGLEAF PINE

By E. W. Gemmer

Every one in the South is familiar with the tap-root of longleaf pine. We see it in washes, road cuts, clay pits, and almost any place in the woods where soil has been removed. That the pine has a system of lateral roots of almost unbelievable size is probably very much less known.

In undertaking to study the roots of longleaf pine on the Choctawhatchee National Forest, the forest service last winter washed the soil away from around the roots of two longleafs, three inches in diameter breast high and 20 feet in height. The method of washing consisted of playing a stream of water from a fire hose on the sandy soil around the roots of these trees. Due to the sandiness of the soil it was easily moved from the point of contact but immediately settled when out of the direct force of the stream. To remove this loose sand a device based upon the principle of a jet blower was built, whereby a stream of water was shot into a three-inch pipe which sucked the sand into the pipes and deposited it some 60 feet from the "diggings."

The amount of soil necessary to be removed to expose the roots was amazing. The roots of one tree occupied an elliptical area of 150 square feet, the longest axis being 19 feet and the shortest 10 feet. The laterals branch from the tap-root immediately below the root collar and in general occupy a zone from one to three feet beneath the surface. The roots therefore had contact or had access to the moisture and nutrients of approximately 50 cubic yards of soil, not considering the tap-root.

The tap-root was five and a half feet long, stocky, and a firm anchor for the little tree. From this root a few small laterals penetrated the deeper soils not invaded by the major laterals.

When we consider the dimensions of the roots of this small sapling we can well wonder what are the dimensions of a mature longleaf. Examination of several have shown that roots one half inch in diameter are not infrequent at 30 feet from the tree, or twice the radius of the crown at that point.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1928

THE PHYSIOLOGY OF THE DUCTLESS GLANDS

By Professor N. B. TAYLOR
DEPARTMENT OF PHYSIOLOGY, UNIVERSITY OF TORONTO

Thirty years or so ago the study of the ductless glands was a field of practically virgin soil. If we should look into a text-book of physiology of that day we would find the subject disposed of in a very few words. Since then much has been learned and the work that has been done on these hitherto little known glands is enormous. Each year, literally millions of hours of laboratory and clinical work are performed and thousands of papers are written upon the subject. Unfortunately, the great bulk of this work is quite barren of any real or lasting value, for just as a ton of rock must be mined and milled in order to secure an ounce of gold, or several tons of pitchblende be treated to obtain a gram or two of radium, so an immense amount of work must be done by the laboratory mills in order to recover a few grains of truth. We read, from time to time, in the daily papers, in semi-scientific publications and in the advertising literature of some of the drug houses, sensational and glowing accounts of the activities of these glands. But most of these glittering tales are misleading and arise from nothing more genuine than a very vivid imagination.

The qualifying or negative word "ductless" implies that these glands are peculiar and distinctive in being without ducts. It implies also that they were discovered later than the more usual type of gland with ducts. It suggests something new and out of the ordinary.

A word first with regard to the usual type of gland. These have been familiar to anatomists and physiologists for hundreds of years. Each is composed of a mass of cells arranged in one or other definite pattern so as to form myriads of tiny spherical cavities. On the outside of the wall of each cavity are blood vessels so that one side of each cell is practically in contact with the blood. From the blood flowing past their doors the cells take what chemical materials they require, and with these raw materials manufacture in some mysterious way a very complex substance which they pour into the bowl-like cavities. This material, the gland's secretion, passes into fine hair-like tubes which lead, one from each of the numberless cavities. These fine tubes are the ducts. They join with one another and form larger ducts. These in turn, join to form larger ones, until finally the secretion finds its way into one or two large tubes which open into one of the body cavities, the mouth or intestine, for instance. The arrangement of the ducts is like the stem system of a bunch of grapes —the hollow masses of cells representing the grapes.

Some, such as the tear glands, the sweat or mammary glands, empty upon the surface of the body. Since the activities of many of these glands are as-

sociated with experiences of every-day life—crying, sweating, salivation, etc.—it is not surprising that they should have been known for so long. They are characterized by two main features. Their secretions are collected by ducts and through these they are poured either into one of the body cavities or upon the surface of the body. In short, they are glands of external secretion.

The ductless glands pour their secretions directly into the blood stream. None of their secretions pass outside of the body. They are on this account also called the glands of internal secretion, endocrine glands or simply the endocrines. Their secretions are also known as hormones. The cells of these glands take in their raw materials by the front door—the arteries—and after fabricating a most powerful chemical material, turn the finished product out at the back door—the veins. Thence the hormone is purveyed to all parts of the body.

These glands are little chemical factories of a marvelous ingenuity; and what apparently miraculous effects their concoctions can bring about! Nothing more wonderful was ever dreamed of by the ancient alchemists with their elixirs and potions. It is the action of one of these secretions that paints the plumage of the male bird in such brilliant colors and also prompts its song. Others cause the growth of bone and direct the development of stature along normal lines—overactivity of this or underactivity of that, and a giant or a dwarf is made. Others influence various psychic processes—instinct, emotions and intelligence. In order that mind and body shall be healthy and normal all the glands must pour their secretions into the blood stream in proper and due proportions—none must be a sluggard, nor yet overzealous in performing its duties.

Some of the glands are of such a size and prominence that they could not escape the notice of the ancient philosophers. Their uses were pondered and speculated upon and many fanciful conjectures were made to account for their presence in the body. But their true functions were undreamed of—they were beyond even the imagination of those days.

Before the discovery of their true functions the control of the various parts of the body was believed to be vested entirely in the nervous system. It was the master tissue. It was the headquarters staff which issued its orders to the various organs and its authority was believed to be supreme. With the discovery of the ductless glands, an entirely new type of control of the bodily function was brought to light. Their influence, if less evident than that of the nervous system, is nevertheless just as important in their own particular sphere.

The *internal secretions have authority* over slowly moving processes, such as the development of particular organs, the growth of the body as a whole and the metabolism of food materials—processes measured by hours, months or years; whereas the nervous system presides over those rapid processes of thought—muscular movement and the external secretion of glands—processes measured by fractions of seconds (or minutes).

There are many sides from which the functions of the ductless glands may be viewed. I might, for instance, discuss them in their relation to character or to personality or heredity—or even to morality or criminality! And there is little doubt but that they have an influence upon some or all of these, but so far science has been unable to place its finger upon anything very definite. Or, I might discuss them in their relation to our "decline into the vale of years," as the poet with such a pleasant euphemism refers to old age. But this side of the question, which has received a great deal of attention in France and on the Continent, is so befogged by pseudo-science and beset with quackery that I would rather leave it alone. I

prefer to take up more definite and known effects, effects that can be proved by direct observation or experiment, and to avoid the more speculative side of the subject, which after all is no stranger than the truth.

Several methods have been and are still made use of to unravel the mysteries of the endocrine glands. In the first place, extracts of the gland tissue may be prepared which may then be injected into animals and a study made of their effects. Secondly, particular glands may be removed from animals and the subsequent life history of these animals watched, taking careful notice of their subsequent development, growth or any unusual symptom. Or, thirdly, we may study diseases in the human subject in whom a particular gland is known to be deficient or overactive.

I shall consider first a gland with which every one to some extent is familiar. This is the thyroid, which lies beneath the muscles of the neck embracing the larynx. When enlarged inordinately, it constitutes the condition known as goiter. All the methods of investigation which I have mentioned were used in the study of the thyroid before any clear idea of its functions was formed.

A certain slight enlargement of the thyroid above the average is an adjunct to feminine beauty. Indeed, one of the older anatomists thought that therein lay its premier function. It gives a pleasing fulness—a roundness to the contours of the neck, no doubt. This fact was not lost sight of by many of the old masters who carried the idea to extremes and painted their maidens with necks which verged upon the goitrous.

The thyroid's greatest power for beauty, however, lies not in its size or its shape, but in its secretion. Every one who has ever seen one of those unfortunates who, from birth or shortly after, had been deprived of his thyroid secretion will know what I mean.

In Switzerland, in the valleys of the Alps, there was to be seen a type of dwarf known as a cretin. A cretin is the direct result of the absence or extreme deficiency of the thyroid hormone. These individuals were truly the most pitiable and grotesque parodies on mankind. They were stunted and deformed in stature and mentally defective or quite imbecilic. Their features were misshapen and flabby. The brow was low, the bridge of the nose depressed and the nostrils wide; the tongue appeared too large for the mouth, which was coarsely moulded. The skin was thick and the hair dry and sparse. I think the description of Caliban must have been inspired by the poet having at one time seen a cretin. Cretins never grew up, but remained for the rest of their lives children in mind and body. Yet, had they been Peter Pans—attractive, happy and intelligent children—all might have been well. But no, they dragged their uncouth bodies through a drab existence, a burden to themselves and their families—or a charge upon the community. The word "cretin" is simply a corruption of the French for "Christian"—*chrétien*—used in the same sense as the English words "innocent" or "simple" are applied to the feeble-minded.

Though cretins were more common in Switzerland than in other parts of Europe, they were by no means confined to that country. Osler, "within a few years," as he says, was able to collect the histories of fifty-eight cases in Canada and the United States. Cretinism was at one time not uncommon in England, especially in Derbyshire. But it was in the valleys of the Alps, of the Pyrenees, in the Tyrol and in the Himalayas that it was seen most frequently.

It was not until the gland was removed in young animals that a clue to the cause of the condition was uncovered. Sir Victor Horsley, the famous London surgeon, performed this operation upon monkeys, and showed that the symptoms which followed were prac-

tically identical with human cretinism. Through this work the responsibility for the cretin was definitely fastened upon the thyroid. This was the gland at fault.

The questions had still to be answered: "Why is cretinism common in certain regions and practically unknown in others?" "Why does the gland fail to perform its proper functions?" The most generally accepted answer to these questions was that the drinking water was at fault. Even as late as 1910 Sir Hector Mackenzie, a pioneer in this field, wrote, "the most potent cause is the water used for drinking purposes." He admitted that the particular something in the water which affected the thyroid in this way was unknown. Later, however, it was thought to be an infecting organism (McCarrison).

Without going further into detail, I may say that the question has at last been settled. It is not due to something in the water that should not be there but to something that is not there which should be there, if I may so express it. It is due to a dearth of iodine in water and food. For this knowledge we are indebted to Marine, of Cleveland, who showed a few years ago that thyroid disease in brook trout could be cured by the addition of minute amounts of iodine to the water in which they swam.

That explains why cretins are practically never seen on the seacoast. The sea is an inexhaustible storehouse for iodine, which finds its way into the food and the drinking water of the coast's inhabitants. It is always in inland territories that thyroid deficiency is seen—particularly in the mountains and the high land, since they, as a rule, are farther removed from the iodine supplies. Analyses of the soils of goitrous districts have shown a marked scarcity of iodine. Chatin, a Swiss, pointed this out seventy-five years ago, but no attention was paid to the observation.

The thyroid must have iodine in order to manufacture its secretion. Without this element it struggles on as best it can, but it can not make bricks without straw. It becomes enlarged, yet the enlargement is made up, to a large extent, of worthless tissue with its spaces filled with an impotent fluid. The important glandular tissue has degenerated, and, though the gland is of greater bulk, it is a fraud and is quite incapable of manufacturing an active secretion. We would also find that such a gland was almost barren of iodine, or at any rate, held but a fraction of the normal amount. It is now an axiom of thyroid pathology that the larger the gland the less is the iodine which it contains.

This is the usual way in which cretinism occurs—following goiter, which destroys the functional activity of the gland. But in rare instances thyroid function may be destroyed by some acute disease of childhood—or rarer still, some unlucky individual may be born without one.

A similar condition, and one having the same cause, may arise in adult life. It is known as myxedema and is essentially the same as cretinism. There can, of course, be no stunting of the stature or mal-development of the bones, since it appears after the period of growth. Myxedema was common in the same regions where cretins were found.

In my discussion of cretinism and myxedema, I have deliberately kept to the past tense, for the very good reason that they are practically things of the past. Medical science in its progress has swept them from its path. We might travel through the Alps to-day, and I do not think that we should see a single cretin, unless it was a case of long standing.

Cretins and myxedematous subjects owe their changed fortunes to an English physician, Dr. George Murray, now emeritus professor of medicine at Manchester. It occurred to this investigator to extract the thyroid glands of sheep

with glycerine and to inject this into the subjects of thyroid deficiency. It is interesting to recall how this idea first came to Murray. He read of an operation performed by two foreign surgeons, Bettencourt and Serrano, in which they had acted upon the suggestion of Sir Victor Horsley and grafted a portion of a sheep's thyroid beneath the skin of a victim of thyroid deficiency. They reported an improvement in the condition. Murray says, "this observation indicated to me that the gland carried on its functions by means of an internal secretion." He, therefore, concluded that it might be possible to extract this secretion from the glands of animals and that it might serve as a suitable substitute for the secretion that was lacking. In 1891 he reported the results of his first trials with the extract.

Of all the discoveries in the field of medicine, this was one of the most brilliant. The extract fulfilled the hopes of even the most sanguine. Its success was complete. It was able within a remarkably short time to conquer all the symptoms of thyroid deficiency in the adult—that is, myxedema.

His success with the cretin depended upon how long the condition had existed before treatment had been commenced. Obviously, not such great benefits could be expected in a case which had existed for years where brain, bone and muscle had been confirmed in their abnormal state. Yet even in these the improvement was often very striking. But in the early cases the effects appeared to be little short of miraculous. No potion brewed in magic cauldron ever produced a greater change than did Murray's extract. As though enchanted, the stunted and gnome-like body of the cretin grew to normal proportions. The ugly mask fell from the face, and the limbs took on the human grace which Nature had hitherto denied them. But, greatest benefit of all, the light of reason returned to the clouded mind, and in a short time these apparently hopeless imbeciles were turned into happy and intelligent children. It is no longer necessary to inject the extract, for it can now be taken in tablets. To-day there should be no cretins under forty years of age. If one younger than this should be seen he is a sad reproach to some one—whether physician or parent—who has failed to bring to this blighted one the certain cure which is ready at hand.

There is another reason why cretins are rare to-day, and that is, the occurrence of goiter is prevented. The cause is removed. Iodine is added to the drinking water or the food, or given in small doses a few times a year to the children of the Swiss cantons and other regions where goiter is prevalent.

There is little doubt, then, of one function of the thyroid gland. It controls the growth and the development of both body and mind. It takes iodine and other materials from the blood and manufactures a secretion or hormone which produces these effects.

In order to bring further conviction, I shall cite a very interesting experiment that was carried out a few years ago upon tadpoles—ordinary pollywogs, whose destiny is, as you know, to grow into frogs.

A group of tadpoles which had been hatched from the same batch of eggs a short time previously was placed in a small aquarium. A number of these creatures were operated upon, and their thyroids removed—rather small subjects, you might think, for a major operation, and rather poor risks, too. But a certain proportion of them made a good recovery and continued to swim about after their convalescence, just like a number of their brothers who had been allowed to keep their thyroids.

The animals without thyroids, however, never grew into frogs. The experimenter, with his scalpel, had shaped their destinies. The joys of frogdom were not for them. Never were they to

spring from slimy pools to breathe the air or bask in sunshine upon a lily pad. They remained pollywogs for the rest of their lives. They were the counterparts of human cretins in so far as body growth and development went. Since their mentality is scarcely of a measurable quantity, no one can say how they progressed in that direction. They can not be subjected to intelligence tests, nor do we know what their brothers thought of them; so that side of the question must be left to the imagination. Their normal brothers, which were kept under precisely the same conditions, lost their gills and tails, grew arms and legs and matured into frogs in the usual way and in the usual length of time—two and a half to three months.

If thyroid extract was given to the cretinoid tadpoles—a small quantity merely dropped into the water in which they swam, or fresh thyroid tissue fed to them—they commenced to develop in the usual way and in due time were hopping about, perfectly normal frogs.

On the other hand, when extract was added to the water in which the normal tadpoles lived—those which were not deprived of their thyroids—they developed into frogs ahead of time. Their development was speeded up. The gills and tail disappeared and the limbs grew out in about a third of the usual time. It can easily be understood why this should be, for their bodies were receiving an excessive amount of thyroid principle—that manufactured by their own thyroids plus that given to them by the experimenter.

Thyroid function has been tested out on another close relative of the frog family. In Mexican waters there is a strange creature known as the axolotl. It is considered quite a delicacy by the Mexicans, though I think that if you ever saw one its gastronomic possibilities would not interest you. The axolotl is a sort of halfway house along the evolutionary path, between a fish and a frog. It looks like a huge tadpole—for it is several inches long—that had started out to be a frog but thought better of it, and remained a grotesque looking object with gills, a finned tail, square head and short fore and hind limbs. This is the usual adult form of these creatures, they breed in this form, many of them never developing into land animals and a few others doing so very, very slowly. If they are fed upon beef thyroid, even one or two meals is enough, they develop into air-breathing animals. They lose their gills and tail fin and develop air-breathing organs. The head becomes oval and the eyes prominent.

Here is an instance in which an animal—forsaken, as it were, at a certain wayside station in the evolutionary journey—has been brought a step further by an internal secretion. I promised not to speculate, but I can not help but wonder just how important a part the ductless glands have played in the evolutionary process.

The thyroid has another entirely different duty to perform, besides those mentioned before. Its hormone is to the body as a forced draught is to a furnace. It fans the fires of life. You all know that the body shows a very real likeness to a furnace or an internal combustion engine. Its muscles consume fuel and in doing so use oxygen and give out carbon dioxide, just as any combustion engine does. Energy is liberated, heat is produced and work is done. Thyroid extract increases the combustion in the muscles. More heat is produced with extract than without. The fire in each cell burns more fiercely. The metabolism—as the physiologists say—is increased.

In those suffering from thyroid lack the fires are dampened down. They glow dully, not brightly as they should—metabolism is lowered. The metabolism may be altered 50 per cent. either way by an increase or a decrease in thyroid secretion. On this account, very

serious effects will result if a normal individual should take thyroid extract for any length of time, for in that case the administered dose added to the natural secretion would increase the combustion within the body to a dangerous degree. Sometimes the thyroid has an exaggerated sense of what is required of it and manufactures more of its very potent secretion than the body needs. The symptoms of overdosage soon become evident. I shall not dwell upon the details of this condition. There is, of course, increased metabolism which requires special methods for its detection. The most evident feature is protruding eyeballs, though it is by no means certain that this symptom can be laid at the thyroid's door. Indeed, there is much evidence that it can not.

Ever since Murray showed that the functions of the thyroid were due to an internal secretion and that this could be extracted, many investigators have endeavored to isolate the active principle, or essence, one might say, from the more or less crude extract which he first obtained. As a result it was not long before some knowledge of the chemical nature of the active principle was gained. A few years ago this principle was obtained in pure form by Kendal, of Rochester, Minnesota. He "dubbed" it thyroxin. It contains iodine, about 60 per cent., combined with certain well-known organic materials. The iodine radical is believed to be responsible for the growth-promoting functions of the thyroid, and part of the organic radical (pyrrol) for the effect upon metabolism. For, if the iodine portion be broken off, the remainder still increases the metabolic rate, yet it has now lost its influence upon the metamorphosis of tadpoles. On the other hand, if the pyrrol group alone is broken off, the material exerts its usual effect upon the tadpole.

Harrington, in England, within the last couple of years, has actually succeeded in manufacturing this material in the laboratory—that is, in producing it artificially from its chemical constituents. It has all the physiological properties of the natural product. But it, as well as Kendal's thyroxin, is many times more powerful than Murray's crude extract; an almost insignificant amount will produce the most profound effects. It may be looked upon as the quintessence of the thyroid juice—a superextract.

The pituitary is another ductless gland which has just as important duties to perform as the thyroid. But it is only a fraction of the size of the thyroid. In man it is scarcely larger than a cherry and lies like an Atlas at the base of the brain with the huge hemispheres heaped above it. And like Atlas, its responsibilities are great, for, if it is removed or destroyed, the whole body is thrown into chaos. It is cast into an abyss from which all the gods are powerless to raise it; death follows inevitably and swiftly. As may be seen, this gland is composed of two parts which, though they are in intimate contact with one another, have entirely different functions to perform. The two divisions are spoken of as lobes, the anterior and the posterior.

The pituitary has been a puzzle since ancient times. It is only within recent years that a glimpse of its true functions has been allowed us. Since it lay on the floor of the skull not far from the root of the nose, some of the ancient writers thought that it existed for the purpose of secreting mucus into the nostrils—indeed, that was how it got its name; pituita, mucus and phlegm were cognate terms in the middle ages. Others, with perhaps more poetry in their make-up, thought that it was the throne of the soul.

As I have said already, one of the main avenues of approach to an understanding of the internal secretions has been through a study of their disorders in the human subject. The first step

toward our present-day conceptions of pituitary function was made by the French physician, Pierre Marie. It was he who first described a condition characterized by overgrowth of the bones of the face, hands and feet. The enlargement of the facial bones was seen particularly in the ridges above the eyes, in the nose and lower jaw. In some cases reported by Marie this member measured 18 inches from ear to ear and the chin was some 4 inches deep. The soft tissues also were thickened, the combination of fleshy and bony overgrowth producing extreme coarsening of the features. This in many cases amounted to grotesque ugliness. The bones of the hands and feet, especially the former, showed a similar overgrowth. This was no moderate enlargement, for the hand of one of these individuals might be double the size of that of a normal person of the same height.

Marie ascribed this condition to disordered function of the pituitary and called it acromegaly, which any Greek scholar would at once tell us simply meant "big extremities." Marie thought that it was the result of depression of the pituitary function, but we know now that it is due to just the reverse—increased secretion by this gland. The disease comes on more or less gradually, but the changed facial expression is rendered very noticeable if a photograph of the subject, taken perhaps five or ten years previously, be compared with the same person in the flesh.

The disease, if it progresses, is invariably fatal, and in all these cases an enlargement of the anterior part of the pituitary has been found after death. There is no doubt, then, that it is this part of the pituitary which is at fault.

Sir Arthur Keith, the noted anatomist and anthropologist, has thrown an interesting sidelight on this condition. While classifying a collection of skulls in the museum of the Royal College of Surgeons in London, he came across one that was undoubtedly acromegalic. He at once recognized the prominence of the bone above the eye sockets, the massiveness and elongation of the lower jaw and the general enlargement of the face area of this skull. The other stigmata of acromegaly were unmistakable. But what struck him most was the remarkable resemblance which this skull bore to the skull of Neanderthal man—one of the earlier of the prehistoric men in Europe. By careful measurements of the two skulls—the acromegalic modern and the normal prehistoric—he found that each showed the same essential characteristics. Upon the skulls of the higher apes are also seen many of the features of the acromegalic skull.

These facts prompt the question: Is the pituitary of man of to-day less active than was that of prehistoric man? In other words, was a secretion which would be considered excessive and pathological to-day normal and physiological to Neanderthal man? We are also tempted to ask whether a gradual lowering of pituitary function has been an aid or an important factor in the evolution of the facial and other skeletal characteristics of modern man? These questions may be asked, but no one, I think, has been bold enough to answer them dogmatically. And there is one great difficulty in considering these suggestions. We shall show in a moment that the growth-promoting power of the pituitary is not confined to the bones of the face and extremities, but extends to all the bones of the body. We would, therefore, expect—if the gland had the effect which Sir Arthur suggests—that the prehistoric man with the beetling brows and the massive jaw would have been a giant. But he was nothing of the sort; he was in fact below the average height of modern man.

Acromegaly is a disorder of the anterior lobe of the pituitary in adult life, that is, after the normal period of growth. But this part of the pituitary

may suffer the same disorder in earlier life, that is, during the growing period. The gland may, just as in the case of acromegaly, become too zealous and secrete an inordinate quantity of its very powerful hormone at this time. When it does, it is not only the bones of the face and extremities which overgrow, but all the bones of the body are urged into an extraordinary overdevelopment. In this way are giants made. Those men of tremendous stature who earn their livelihoods in circus sideshows are instances of overactive pituitary glands. Some of these giants reach the "altitude" of eight or nine feet. They would knock their heads against the ceilings in the modern Toronto house and would need to bend nearly double to pass through a doorway. The tallest which I have seen reported was a Finn, nine feet five inches. But there has been a Chinese giant reported who was eight feet one inch, and an American recorded by Dr. Harvey Cushing as over eight feet two inches. These are the extreme cases, but there are many degrees of giantism or gigantism, as the condition is called. A certain French baron some years ago sought by encouraging the inter-marriage of giants and giantesses of this type to produce a race of supermen, but the experiment, for which a million francs was subscribed, proved a dismal failure. The gigantic parents had average sized offspring. And this is a characteristic of pituitary giantism. The giants are usually the children of normal parents and they themselves have normal children.

The pituitary by these excesses—acromegaly and gigantism—has revealed itself. There is every reason to believe that its physiological function is to urge the growing bone, within normal limits.

If the pituitary can increase its output above the normal and produce giants, the question naturally arises whether it ever fails to manufacture enough of its hormone and produce dwarfs? It does, and there are two kinds of dwarf which may result from a deficient pituitary secretion. Only one of these is caused by deficiency of the anterior lobe alone. He resembles the midget, but differs in certain essential features from that popular attraction of the sideshows. The midget remains unexplained; he may be a pituitary case, but there is no evidence that he is. The true anterior lobe dwarf is a rather quaint little person. He (or she) is perfectly proportioned, delicately formed and usually of a pleasing appearance. To the casual observer he appears normal in every way, except in size, and his intelligence is usually of the average grade, though in some cases it is below the normal. They are men and women in miniature—adult figures, seen as it were through the wrong end of the telescope, for their bodies are never proportioned upon the plan of the child, that is, with relatively large heads. Nor are their facial features childlike.

Very frequently the posterior lobe as well as the anterior is deficient. The disorder, then, is one of the pituitary as a whole. There will be seen a combination—a mixture of effects, some caused by one lobe, some by the other.

Before these combined effects can be described, the functions of the posterior lobe must be outlined. The duties of this part of the gland are not so clear as those of the anterior. True, an extract may be obtained from it which produces immediate and very definite effects when injected into an animal. It causes, for instance, a rise in the blood pressure and induces contractions of the muscular walls of various organs of the body. But whether they are part of a true physiological function or merely effects produced through artificial methods of extraction can not be said.

There is no evidence that the posterior lobe is concerned in any way with the development and growth of the bones.

There is one function, however, of which there seems to be no doubt. It is concerned with the disposal of sugar by the body. When its secretion is produced in insufficient amount, there is a remarkable increase in the quantity of sugar which the body can use. If a normal person takes a large quantity of sugar it is not all utilized by the body cells. The excess can be found in the blood and is later excreted. The subject of posterior lobe deficiency can utilize several times that which the normal individual can use. It would appear that this excessive utilization can not be accounted for by increased *combustion* of the sugar and consequently by a greater production of heat. For these subjects have a body temperature that is lower than the normal, and the general metabolism is actually depressed. The excess sugar is evidently used for the formation of fat, since the outstanding feature of these subjects is the great overdevelopment of fatty tissue. Injections of an extract of the posterior lobe produce the opposite effect—a reduction in the body's ability to use sugar.

Pituitary disorders of this nature are not infrequently seen in children. Many children, as we know, have a tendency to increase their fatty tissue at a certain age, and this may be due to a normal variation of the posterior lobe hormone. But these individuals with posterior lobe deficiency are not just ordinary fat children. Their fatness is really extraordinary; they are veritable roly-polies and present a striking appearance. They have often a voracious appetite and have, even for children, an inordinate longing for sweets of all kinds. They are, as a rule, somewhat below par mentally, progress slowly at school and show an unchildlike lethargy—ready to sleep at any time. Dickens' Fat Boy, I think, must have been a pituitary case; and the little fat boy whom many of you may have seen in the movies, as a member of that humorous group of children known as "the gang," has, I think, if the truth were known, a pituitary whose posterior lobe is not quite doing its duty. Great obesity may result from posterior lobe deficiency in adults also, and the fat woman of the circus is in many cases, no doubt, an example of this condition. Indeed, the vagaries of the pituitary have proved a great source of profit for the circus proprietor.

When there is a deficiency of the anterior lobe accompanying the deficiency of the posterior lobe, there is a combination of the effects characteristic of both parts of the pituitary. Arrested growth, added to the extreme obesity, produces a remarkable type of dwarf. His length and breadth approach equality. Gigantism with obesity will also occur if overactivity of the anterior lobe be associated with deficiency of the posterior.

Experimental

All these instances go to show the direction in which the activities of the pituitary lie. If disorders of its function produce these abnormalities, it is, I think, logical to assume that its physiological function is to influence the growth of the body within normal limits (anterior part) and to furnish a hormone which controls in some way or other the conversion of sugar into fat (posterior part). Until recent years, little support for these conclusions, arrived at from the study of human cases, could be obtained from animal experimentation. The other two methods of approach—use of extracts and removal of the gland—failed to produce decisive results. Recently, however, Evans and Smith, of the University of California, have been able to show in a truly spectacular fashion the profound effect which the anterior lobe has upon growth. They have been able to prepare an extract of the anterior lobe which has this effect. The experiments were carried out in this way: Pituitary glands (anterior lobe) of the ox were minced and extracted with

salty water. The extract obtained in this simple way was then injected into young white rats over a period of several weeks. Other rats of the same litter were kept under precisely the same conditions and received the same food, but were not injected with extract. These untreated rats served as standards or controls, as they are technically called, to which the injected rats could be compared.

The period of growth of the normal laboratory rat is now well known. It is from 150 to 180 days. At the end of this time it has reached the adult form and size and ceases to grow further. The control rats followed this normal course. The treated rats, that is, those injected with the extract, did not cease to grow when the end of this period was reached, but continued to grow for several weeks afterwards. They finally developed into huge, giant rats. Though they were not, perhaps, as large as the rats that Gulliver adventured with in Brobdingnag, they were at least 60 per cent., and in some cases 100 per cent., larger than their brothers and sisters of the same litter which had received no extract.

The other side of the picture was also outlined by experiment, that is to say, depression of the pituitary function produced the reverse effects—retarded growth. On account of the small size of the pituitary in the rat, it is impossible to destroy one part of the gland without injuring or destroying more or less of the other part as well. There is also the danger of damaging too severely the anterior lobe, which is essential to life. It was, therefore, impossible to produce pure effects of one or the other lobe. The effects were what might have been expected from partial destruction and consequent deficiency of both lobes. The animals became very fat and failed to grow to normal size. They corresponded very closely to the type of dwarfs already described for human subjects, as a result of deficiency of both lobes. These animals, however, usually showed the obesity more than the dwarfing; they were so rotund that they resembled nothing so much as little balls of cotton wool.

Before leaving the subject of the pituitary I must speak of another strange effect which its secretion has upon certain members of the amphibian and reptile families. Many of you no doubt have been fascinated by the way in which some of these creatures, such as the tree toad and certain varieties of lizard, particularly the chameleon, apparently change the color of their skins to match the background upon which they lie or cling. Many fish, also, are endowed with this ability. Even the common frog is of a darker tint in subdued light or on a dark background than it is in bright sunshine, where it appears to become "bleached" to a much lighter shade of green or yellow.

The frog's skin, as you know, is not of a solid color, but is marked with dark spots or blotches which overlie a light greenish yellow ground. This mottling is particularly well marked in one species—the leopard frog. If the dark spots are examined beneath the microscope they will be found to be made up of groups of cells with many branching arms and containing granules of a dark pigment. These cells expand in the dark or in dim light and contract in bright light. Or I should say, rather, that the pigment collects near the center of the cell when the light is bright, but streams throughout the whole cell and into its branching arms when the frog is in darkness. So the blotches become larger and take up a greater part of the skin pattern, and less of the underlying green or yellow pigment of the skin shows through. This action of the cells of the frog's skin was a puzzle to biologists for years. They thought that nerves must be concerned in the reaction, yet this could not be demonstrated with general satisfaction. One competent observer, for instance, was convinced that the reactions were carried

out through the sense of touch in the skin of the toes. For, he said, when the toes were rendered anesthetic by cocaine, the responses did not occur. He thought that the textural qualities—hardness, roughness, etc., of various materials, such as stone, grass, wood, earth, etc., upon which the animal rested, produced color reactions in the pigment cells corresponding to the color of these materials. In other words, the nerves established an association between the texture or any other "touchable" quality of a material and its color. This theory, on the face of it, seemed improbable, and it is not at present entertained.

If a few tadpoles be taken and their pituitaries removed—this can be done quite easily in this creature, for the gland lies in an accessible position beneath the upper surface of the head—very soon we should find that the animals had lost their natural dark color and appeared as mere silvery ghosts of their former selves. This suggests to us at once that the same thing which bleaches the tadpole also bleaches the frog. Does the lack of pituitary secretion cause the pigment granules to retreat to the center of the cells, and does the presence of the hormone in the blood cause them to spread throughout the cell-body? We can easily put this suggestion to the test. If a frog be injected with an extract of the posterior lobe, its skin within a moment or two becomes coal black. After removal of the pituitary, on the other hand, the frog is unable to alter the color scheme of its skin when the illumination of its surroundings is altered. There is little doubt, then, of the action of this portion of the pituitary upon the pigment cells of the frog. If the eyes of a normal frog are covered with some opaque material, the color reaction does not occur.

Now we can form a picture of the mechanism by which the animals change their tinting according to the light. If the frog is in a bright light or upon a light background the retina is stimulated by the rays of light. Impulses pass along the optic nerves to the brain, and some of these impulses are sidetracked to the pituitary's posterior lobe and its secretion is suppressed. The suppression persists so long as the rays of light are entering the eyes. The pigment cells, however, do not at once become pale, for the secretion which had been circulating in the blood, and which keeps the cells expanded, must first be used up. This takes a certain time, but as soon as it is complete the cells appear to shrink, and a sickly greenish yellow pallor creeps over the amphibian skin. In this way does the frog—leopard or other variety—change his spots; but the Ethiopian can not change his skin, for no corresponding reactions have been shown to occur in man or in any of the higher animals.

Limited space permits me to consider only two ductless glands. I have chosen these two because more is known of them than of others which I have not touched upon. I might, for instance, have discussed the parathyroids—those tiny glands which lie beneath the thyroid. They are essential to health and, indeed, to life itself, though even in an ox they are no larger than a bean. They govern the amount of calcium in the blood. If they are removed the calcium is reduced, and an extract prepared from them when injected into an animal causes the calcium to rise.

Or I might have taken up the adrenal glands, which lie near the kidneys and are believed by some to enhance the reactions of the primitive emotions—hate, fear, anger, etc. There are also those glands which have been shown to exert such influence upon the development of the secondary characteristics of sex, such as the plumage of birds and the antlers of stags. There are also the pineal gland and the thymus, the one lying deep in the brain, the other deep in the chest, and both shrouded in the deepest

mystery. There is also the pancreas, which pours insulin into the blood stream, but the study of this hormone is a very large subject in itself.

I have treated the glands of which I have spoken as though they were quite independent one of the other. This is unavoidable, because this is the way in which they have been studied, and this is the way in which most of the information regarding them has been gained. Yet there is no doubt that their actions are very closely related one with another and that it is purely artificial to study them in water-tight compartments. It is, however, at the present time, impossible to do otherwise.

We should look upon the secretions of the ductless glands rather, I think, as forming with the blood a suitable environment—an appropriate fluid medium to bathe the cells of the tissues. When all secretions are present in their correct proportions the cells are healthy, they flourish and grow normally. If, on the other hand, one or other constituent of this nicely balanced mixture be present in reduced or excessive proportion, the environment becomes unsuitable and the cells suffer. Their development along the particular paths which hereditary impulses direct them is thwarted, and abnormalities result.

In order that there shall be physiological harmony, each endocrine gland must play its part in tune with its fellows.

COUNTING ATOMS AND ELECTRONS[1]

By Dr. L. F. CURTISS
U. S. BUREAU OF STANDARDS

In the development of the subject of atomic physics, information is frequently necessary which can only be obtained from the study of individual atomic processes. Although much of our present knowledge is based on investigations of atomic aggregates, and conclusions have been drawn from the results which represent the average of millions of individual reactions, this method does not always give the information required, nor is it always safe to deduce what a single atom may do from the actions of atoms *en masse*. In fact, most of the important experiments which opened the way to what might be termed modern atomic physics dealt with individual atoms. As a striking example may be mentioned the well-known experiments on deflections of α-rays when passing through solids, performed by Sir Ernest Rutherford by the scintillation method. By counting the scintillation of individual α-particles on a zinc blende screen he was able to observe the behavior of individual particles and to show conclusively that the great preponderance of the mass of the atom was in a very small region near the center. This marks the beginning of course of the nuclear theory of atomic structure which still forms the foundation of all atomic speculation regardless of the manner in which these speculations are developed.

With each new development in atomic theory the importance of methods of this kind grows. It is therefore desirable to give special attention to such means of study. In addition to the scintillation method mentioned above for counting α-particles, there exist at present only two other ways in which observations of this kind may be made. One is the cloud-chamber originated by C. T. R. Wilson, and the other the electrical counter devised by Geiger. Although the scintillation method only permits a counting of the number of α-particles which strike it, the cloud-chamber makes the whole path of the α-particles visible, which has great advantages. Unfortunately the chamber only makes visible those processes which occur within about one one thousandth of a second and this imposes certain limitations on its use. The Geiger counter is very similar in its use to the zinc sulphide screen of the scintillation method but does not require a darkened room and will also count β-particles, *i.e.*, swiftly moving electrons. It also may be arranged to be self-registering so that permanent records of its count may be made automatically.

It may be appreciated from the above brief summary of these methods that the Geiger counter is capable of many important applications. However, its use is attended by several serious handicaps. One is that very little or nothing has heretofore been known regarding the real nature of its action. This has led to cut-and-try methods for producing working counting chambers, which were not always reliable. Even under best conditions great care and patience are required to avoid spurious effects which may vitiate the whole experiment.

[1] A more technical discussion of the subject will be found in a paper in the June issue of the *Physical Review* by the author. The present article is published with the approval of the director of the Bureau of Standards, Department of Commerce.

In view of this situation there is need of improvement in the counter which can only be accomplished when more is known about its operation. I wish now to describe some attempts to determine the essential conditions for a sensitive counter. The results have given some interesting information which leads to a better understanding of the nature of the action of the counter and which may lead to considerable improvement.

For the benefit of those who are not familiar with the Geiger counter, a brief description of its construction and use may not be out of place before we begin to discuss the experiments. Essentially in its usual form the counter consists of a cylindrical metal tube, closed at one end save for a small hole to permit α- or β-particles to enter. An insulating stopper fits the other end and supports axially the "point" which consists usually of a finely sharpened steel or platinum needle, occasionally with a minute ball fused on the end. Fig. 1 shows a diagram of such a counter. In use the walls of the counting chamber are charged to a constant potential of from one thousand to two thousand volts, depending on the size of the chamber, the nature of the point and its distance from the face of the chamber. It is customary to connect the chamber walls with the positive terminal of the battery, but it may be operated with the potential reversed, as will be discussed later. The point is connected to some sensitive detecting device such as a string electrometer or a vacuum-tube amplifier. When properly adjusted with a suitably prepared point, a "kick" of a string electrometer is obtained for each α-particle that enters the chamber through the opening in the front. This means that in some way the α-particle starts an ionization current between the wall of the chamber and the point, causing the latter to charge up. However, this current once started almost instantaneously stops and the

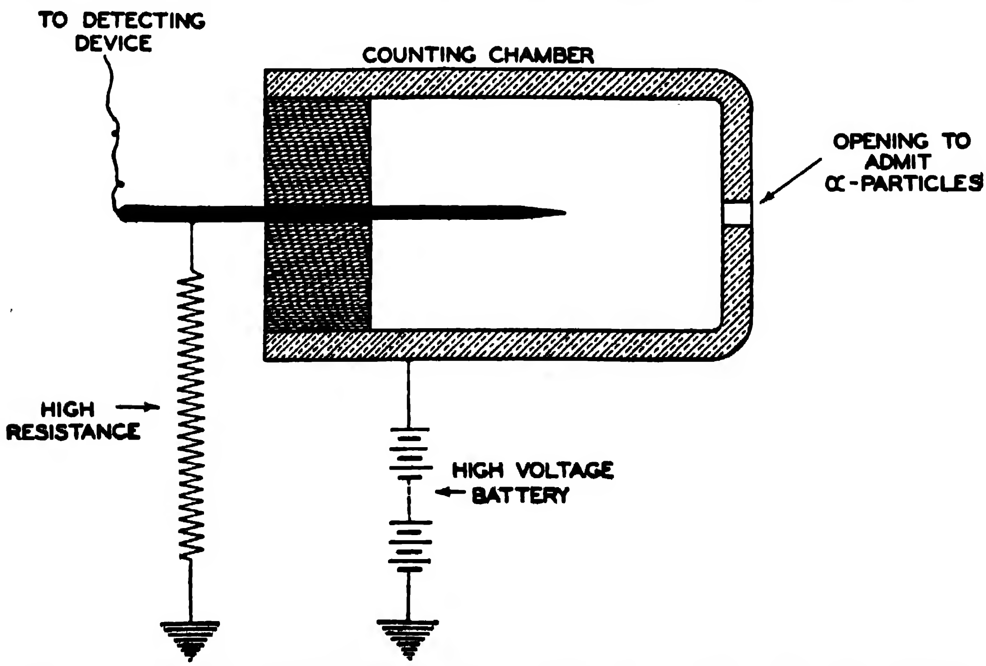


FIG. 1. A DIAGRAM SHOWING THE ESSENTIAL FEATURES OF THE GEIGER ION COUNTER.

counter returns to its original condition, if provided with a suitably treated point. The point is connected to ground through a high resistance which enables the charge acquired by the insulated system of the electrometer to leak off in time to receive another charge from the next α-particle to enter. It has been found very hard to explain why this ionization current does not continue, once started, so that it would be impossible to use the chamber for counting. All that has been known is that some special heat treatment is necessary to put iron or platinum points in a condition to act in the usual way. Heretofore, practically no other metals have been used successfully. There has been considerable discussion regarding what change is produced in the metal by repeatedly heating or fusing in a flame, the usual method of preparing a point. However, no satisfactory conclusions have been drawn, mainly because too little information has been available concerning the behavior of points under various conditions. In fact, so much confusion has existed that some investigators have postulated that the sensitive surface of the counter is not on the point but on the inner wall of the chamber. This is not the case, as we will see before we have finished with this discussion.

A few pertinent facts concerning the behavior of the counter, as reported by other investigators, should be summarized here for use later in the discussion. What might be termed the amplification factor of the counter is of considerable interest. Each α-particle of course is a single ion, being a doubly charged helium atom. By measuring the current which flows in the chamber for each α-particle counted, it is possible to determine how many ions are produced within the counter for each count and, therefore, how greatly the original stimulus has been magnified by the counter itself.

This has been done by various workers under slightly different conditions, but the average estimate is about 10^7 or 10^8 ions for each α-particle, so that one can appreciate at once what a powerful method is here offered. This also makes it evident that, by choosing a suitably high value of the high resistance, a "kick" of several volts may be communicated to the string electrometer so that for visual observations no further amplification is required. Another interesting fact that has been known is that very closely the same number of ions are produced in the counter during its operation for every particle that enters. To make clear what is meant by this statement it should be recalled that we really deal here with two types or stages of ionization of the gas in the chamber when a particle is counted. There is what may be termed the "primary" ionization, which is always produced by an α-particle when it traverses a gas. For example, when an α-particle passes through air at atmospheric pressure it produces about 3,000 ions per mm of path. However, we have seen that about ten thousand times as many ions are produced in the counter and this portion may be termed the secondary ionization or ionization by collision, which will be referred to later. Now it makes very little difference how far an α-particle penetrates into the counting chamber since the primary ionization contributes so little to the total effect. This primary ionization may be regarded as the trigger which sets the counter off. The fact that the ionization by collision part of the current remains approximately constant from one count to the next obviously means that the same quantity of gas is ionized each time and therefore that this ionization must occur in about the same portion of the gas. The full significance of this will appear when we come to a final discussion. A further proof that the primary ionization acts

in the capacity of a trigger is shown by observations which indicate that the lower limit to the number of such ions which must be produced by the α-particle to set the chamber off is relatively very small. This is shown by the fact that, if conditions are arranged so that the α-particles penetrate the chamber by a small fraction only of a millimeter so that only a hundred or so primary ions are produced, the α-particle is still counted.

In the work which will now be described, the writer started from a suggestion made by Geiger in a brief paper on this subject. It has always been difficult for those who have worked with this instrument to understand how the current pulse produced by the entrance of a particle is broken off so quickly. The interruption is almost instantaneous. In the article referred to, Dr. Geiger suggested that a layer of high electrical resistance on the surface of the point might explain this sudden interruption. As the current started it would cause a rise in potential of the point opposing that applied by the battery, thus finally reducing the effective voltage so low that the current would stop. He suggested that this layer might be due to the occlusion of gas within the metal by the heating which is necessary to prepare a point for use. To test the idea of high electrical resistance it seemed reasonable to try films of materials which were semi-insulating, coated over the point. Many such things were tried, such as various oils, lacquers, etc., as well as highly resistant metals, such as selenium. However, none of these was more than partially successful, and even these exceptions were undoubtedly due to the difficulty of coating a very sharp point completely by a thin film. However, during these trials an accidental observation was made which led to a new series of experiments.

By chance a steel needle was dipped in the phosphoric acid from an old drying bulb. This point worked beautifully and at first it was thought that the phosphate formed on the surface might be responsible for this. However, steel needles coated with the phosphate by other methods failed to work. While examining one of these points under a microscope, small bubbles, presumably of hydrogen, were noticed in the film of acid adhering to the needle and it seemed possible that the presence of this gas on the surface of the metal might account for the sensitive condition of the point. This idea was tested in the following ways. In the first place, another acid which attacks steel, such as dilute sulphuric, should produce the same result. This was tried and it was found to work.

A further test of the hypothesis that a layer of gas is responsible for the action of the counter is provided by work with platinum points. If the gas formed by the acid is necessary, then dipping platinum points in acid should not help them. No effect was obtained by heating platinum points with acid. Furthermore, if the platinum point is used as an electrode in electrolysis, the gas thus deposited might be effective, which was found to be the case. Furthermore, it made no difference whether oxygen or hydrogen was deposited. Points prepared by any of these methods so far discussed were not very permanent or reliable, as might be expected. The next step seemed to be to find a better way of retaining the gas layer on the point. It was thought that this might be accomplished by using a catalytic substance. Accordingly it was decided to try some of the well-known metallic catalysts. Platinum black was the first to be tried. A platinum point was coated by electrolysis in a platinum solution. This point worked very well. Since only the platinum black surface should be necessary, steel points were coated with

platinum black merely by dipping them in the platinum solution. These also worked. These results gave great encouragement to the view that the catalytic condition of the metallic surface was necessary for a good point. However, it seemed desirable to subject this idea to more rigorous test. For example, further support might be obtained by working with a metal which can be put in the catalytic condition only by careful treatment. Copper is such a metal. It is significant that copper points have never previously been used in the Geiger counter with any success. Special treatment is needed to obtain catalytic copper; *i.e.*, slow reduction and oxidation at about 250° C. for several hours or days at a time. Copper points were placed in a glass tube which could be maintained constantly at about 250° C., and a stream, first of oxygen, then of hydrogen, was permitted to pass over them for twenty-four hours. At the end of five days these points were tried in the Geiger counter and all gave excellent results.

Another peculiarity of metallic catalysts is their susceptibility to "poisons." It is well known that the presence of such substances as mercury vapor, hydrogen sulphide and sulphur dioxide will under certain conditions ruin the activity of the ordinary metallic catalyst. This seems to result from a strong affinity between the catalysts and these substances and once they are adsorbed, they are not readily driven off, and so modify the surface that the catalyst no longer functions. It should, therefore, be interesting to admit these poisons to a counting chamber while in operation. A chamber was arranged with a side tube so that mercury vapor, hydrogen sulphide or sulphur dioxide might be admitted while counting. The result of this test was remarkably convincing. The instant the poison was admitted the counter at once ceased to function. All sensitive points which have been tried behave in this way. These results are regarded as an emphatic confirmation of catalytic theory of the sensitive point.

Any further doubts on this question are pretty well dispelled by observations with points of copper. As mentioned before copper points in air will not work. But catalytic copper in the oxidized state does. The reduced copper catalyst works in hydrogen but is poisoned by oxygen or water vapor. From adsorption measurements and other data it is well known that the reduced copper catalyst behaves peculiarly when exposed to carbon monoxide or ethylene. Both of these substances are adsorbed much more strongly than hydrogen, so strongly that they may be regarded as poisons for this catalyst. A counter with a reduced copper point was put in operation with a stream of hydrogen passing through it. The hydrogen was then cut off and carbon monoxide allowed to flow through. The counter at once ceased to function. Similar results were obtained with ethylene. To make this correlation still more convincing a freshly cleaned metallic copper point was tried in an atmosphere of carbon monoxide. From chemical data it is known that the carbon monoxide should not be so strongly adsorbed on an ordinary copper surface as to constitute a poison. In this case the copper point worked, although it ceased to work at once as soon as air was admitted. Thus it may be seen that, as far as trials have been made, the behavior of a point of any material under given conditions may be predicted from a knowledge of the catalytic behavior of the material under the same conditions and that the reverse should also be true.

In order to give the reader a little better idea regarding the behavior of the counter under the various conditions discussed, chronograph records are shown in Fig. 2. These records were obtained by connecting the counting

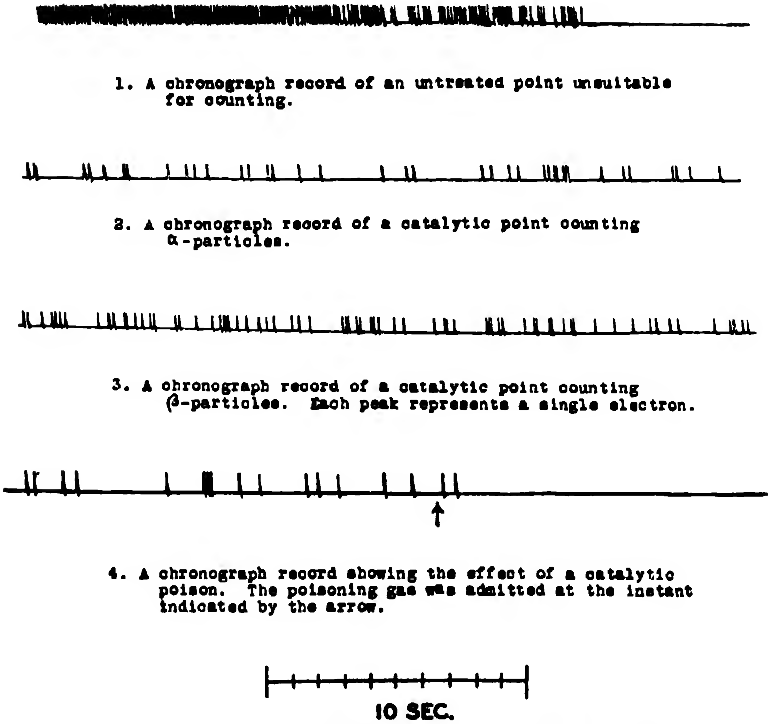


FIG. 2. CHRONOGRAPH RECORDS OBTAINED WITH A VACUUM TUBE AMPLIFIER SHOWING THE OPERATION OF THE ION COUNTER UNDER SOME TYPICAL CONDITIONS.

chamber to a telegraph relay through a vacuum-tube amplifier. The relay then was used to actuate the chronograph. In the first line we have an example of an untreated, freshly sharpened metal point in air. This record was obtained by raising the voltage while particles were entering the chamber until the amplifier responded. The record represents a rapid series of brush discharges in the counter which are unchanged if the source of α-particles is removed. If the voltage is raised a little higher, a true arc strikes, melting the point. In the second line we have a record of a properly prepared point where each "kick" corresponds to the entry of an α-particle. The third line represents the same process for β-particles. In this case each kick represents the entrance of a single electron into the chamber. In the fourth line we have a record showing the result of admitting a catalytic poison into the counting chamber while in operation. The poisoning gas was admitted at the instant indicated by the arrow and as the record shows the point was at once ruined.

With this new information regarding the nature of the sensitive surface requisite for a satisfactory counter, it should be possible to construct a more accurate picture of the processes which take place in the counter than could be done previously. The writer has considered several explanations for the action of the sensitive gas layer and the general behavior of the counter which will now be presented. Before going into this phase of the question in detail, we must recall some features which exist in the counter as a result of its

peculiar arrangements and which play an important part in its action. Referring to Fig. 1 we note that the counter is an ionization chamber with very dissimilar electrodes. One is a point and the other is a very large surface. Under such conditions the electric potential between these two electrodes has a peculiar distribution. We may make this plain by showing in Fig. 3 the variation of the potential between

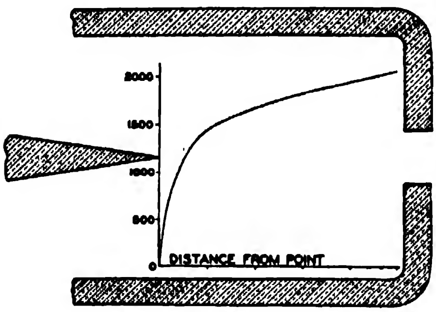


FIG. 3. A DIAGRAM SHOWING THE VARIATION IN POTENTIAL WITHIN THE GEIGER ION COUNTER.

two such electrodes. As may be seen from the curve plotted with axes placed in appropriate positions within the counter, the potential rises very rapidly indeed in the first few millimeters beyond the point and then after that only gradually. Hence an electron released from the point quickly picks up sufficient energy to ionize a gas atom, thus producing another electron in an intense field so that it also soon has energy to ionize and an ionization current is built up exponentially to a comparatively high value in this region where the potential gradient is high as shown by the curve. As soon as this disturbance proceeds to the region where the curve is more gentle in slope, little or no new ionization is produced, as the electric field is only strong enough here to carry ions already formed over to the chamber walls. The existence of a restricted region with intense electric field plays an important part in the operation of the counter and will be referred to again in more detailed discussion of its operation.

It is also important to remember that the counter works with a relatively high pressure of gas. By this we mean at atmospheric pressure or at some considerable fraction of it. The counter can not be relied on at all if the pressure is reduced below about five centimeters of mercury. With such high pressures of course the mean free path of the ions is very short. This means that very intense fields are necessary to give even the electrons sufficient energy to ionize at an impact since they can only acquire kinetic energy while moving freely. The positive ions, due to their relatively low mobility compared with the electrons, never can acquire kinetic energy enough to ionize by impact. When two thousand volts are applied to the counter the positive ions can acquire only a few hundredths of a volt kinetic energy on the average. Since the mean free path is of the order of 10^{-5} cm, if we consider the electric field at its most intense portion equal to 10^3 volts per cm, the positive ion could only acquire about 10^{-2} volts for each free flight. Since it will share this energy equally on impact with the next atom the average energy acquired at any time by the positive ions is small. Of course a few will possess energy much higher than the average, but even this may be neglected when we realize that we require ions with energies of about fifteen volts or more to ionize by impact. This great difference between the electrons and the positive ions is very important in considering the nature of the processes which go on in the counter.

We are now prepared to consider the behavior of the counter in relation to the new facts concerning the catalytic nature of the sensitive surface on the point. In this discussion it must be borne in mind that this layer only func-

tions when the point is negative and it is then indispensable to the operation of the counter. With the point negative when a discharge occurs, electrons must come from the point and go to the chamber walls. It is well known that it is almost impossible to draw electrons from metals from which gases have been thoroughly removed. Consequently we must explain how the electrons are released from the gas layer we now know to be adsorbed on the point and how the catalytic property of rapid adsorption plays a part in the operation of the counter. The only change produced at the point when an α-particle enters the chamber is the arrival of a few positive ions which results from the primary ionization produced by the α-particle. Therefore these positive ions must be responsible for the release of electrons from the layer of adsorbed gas on the point. The diagram in Fig. 4 helps to

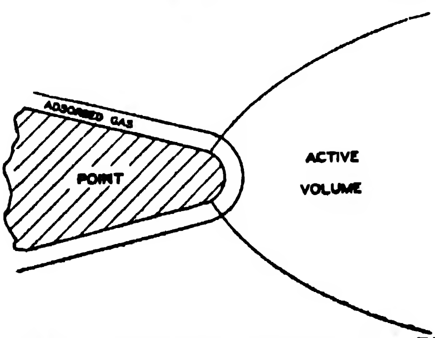


FIG. 4. A DIAGRAM SHOWING THE RELATION BETWEEN THE "ACTIVE VOLUME" AND THE CATALYTIC SURFACE ON THE POINT.

make clear the nature of the problem with which we are confronted. The experimental evidence here presented indicates that there is a layer of adsorbed gas necessary for the point to work which may be represented roughly, as shown in the figure. From the form of the electric field only ions formed within what has been labeled the "active volume" will be able to affect the point. Consequently only the small portion of gas near the point is involved in the process. We are now required to provide a mechanism which will provide for the release of electrons from the metal of the point out into the free gas of the counter by means of the adsorbed gas. We know that the positive ions do not have enough *kinetic* energy to ionize the atoms of the adsorbed gas. However, as soon as the positive ions arrive at the surface of this layer their *potential* energy resulting from their ionized condition is at once available for exciting or even ionizing the gas atoms. For experiments have been performed which show that an adsorbed gas has a lower ionization potential than a free gas. Therefore, the potential energy of these free gas atoms is greater than that necessary to ionize the adsorbed gas atom. Once a few electrons are thus released from the gas in the very intense field existing there, the remainder of the process seems comparatively simple. They at once acquire sufficient kinetic energy to ionize the gas in the chamber by impact. For each electron thus ionizing a new electron is produced, which also may immediately acquire ionizing energy. This process continues as the disturbance moves out toward the chamber walls until we come to the more gentle part of the curve in Fig. 3 when no new ionization is produced. During the initial part of the discharge the ionization current is building up exponentially and this process need continue but a short time to explain the observed amplification of the Geiger counter, *i.e.*, about 10^7. It should also be noted that we are now in a position to account for the sudden cessation of this ionization current, a fact that has hitherto been considered mysterious. This current can continue only as long as fresh electrons are supplied by the point. However, as soon as all the adsorbed gas atoms existing at the

tip of the point in the concentrated field are ionized, the supply of electrons is exhausted. Furthermore, the ionized atoms, plus the accumulation of similar ions from the gas, cause the point to rise in potential and momentarily reduce the intensity of the field in the very region where the electric field is most concentrated. Of course, in a very small fraction of a second, these atoms may recombine, drawing on the "free" electrons of the metal for this purpose, but when we realize that we only require them to stay ionized for the brief space of about 10^{-4} sec. to account for the interruption of the current it is easily seen that this is a possible explanation.

While working on the above explanation it occurred to the writer that if such ionization of the gas layer took place with subsequent recombination there might be a visible flash at the point for each count. This could be tested readily by connecting the counting chamber with a vacuum-tube amplifier, which in turn actuates a relay. For each α-particle entering the chamber the relay is heard to click. A slot was cut in the side of the chamber opposite the point and a microscope magnifying one hundred diameters was focussed on the end of the point. This arrangement was placed in a totally darkened room. After the eye was thoroughly adapted, requiring from twenty minutes to half an hour, a tiny flash was observable on the very tip of the point, appearing as a softly glowing cap. Four different observers were able to see these flashes and all agreed that they were entirely coincident with the clicks of the relay. This experiment was at first considered as strongly confirming the idea of ionization of the adsorbed gas layer. On second thought, however, it became apparent that this glow may be entirely due to positive ions from the gas in the chamber arriving at the point. Since the volume of the counter is kept swept free of electrons by the high voltage, these positive ions have no chance to recombine until they reach the point. At present there is no information available which might give preference to either view concerning the occurrence of this glow. However, since at least two explanations are possible for its appearance, it seemed well to consider further ways in which the electrons might be released from the adsorbed gas.

An explanation has been developed along these lines which would utilize the kinetic energy of the positive ions. We have seen that this is not sufficient to produce ionization, but the arrival of several hundred positive ions each with kinetic energy corresponding to a few hundredths of a volt will raise the temperature of the minute portion of adsorbed gas near the tip quite appreciably at the instant of impact. Davisson and Germer have shown in their recent experiments with reflection of electron beams from layers of adsorbed gas that these layers have a lattice pattern similar to the metal adsorbing them and that the gas layer at room temperature is in a *solid state.* They have also shown that this solid may be melted by raising the temperature a few hundred degrees. Now while the gas atoms are in the solid phase with a lattice structure like the metal, the free electrons of the metal should be able to diffuse readily into this gas lattice since the boundary between gas and solid is no longer clearly defined. If now the positive ions produced by the entry of the α-particle strike such a layer they may raise its temperature locally enough to evaporate a portion of the gas layer releasing the electrons in the intense electric field existing at the tip of the point. These immediately produce additional positive ions which, returning to the point, evaporate further gas atoms. This can continue until the adsorbed gas atoms are all removed from the restricted area near the tip of the point where the field is concentrated. When this occurs the dis-

turbance must cease in very much the same way as described above when discussing the release of electrons by ionization of the gas layer. Furthermore, since by this process the un-ionized adsorbed gas atoms are replaced by atoms from the chamber, these produced the same diminution in the electric field which was referred to it in the other explanation. This would then help in interrupting the current. Actually of course we know that such an effect exists in the counting chamber for, during the actual process of a count, the needle rapidly accumulates a charge, building up a considerable potential. For this reason it is necessary to connect the needle to ground through a high resistance so that this charge may leak off before the next α-particle enters the chamber; otherwise this later α-particle is not counted.

It is rather difficult to decide between these two possible explanations. As far as can now be seen either would account for the action of the chamber and there is some experimental evidence for each. Since the evaporation hypothesis requires less energy from the positive ions, perhaps it is to be favored unless more definite information supporting the former view can be produced. Furthermore, the evaporation idea makes more complete use of the catalytic nature of the point. On the ionization theory all that is required of the catalyst is to retain the gas on the point. In the second case, however, the gas layer is temporarily removed and the strong adsorptive properties of the catalyst are required to restore this layer in time to count the next particle. It is possible that ordinary metallic surfaces might hold sufficient gas to enable the ionization process to occur, but it would seem to require a particularly efficient surface to readsorb a gas layer rapidly enough to count particles which were entering the chamber within one hundredth or one thousandth of a second of each other as has been observed.

Thus far we have been able to account for the principal observations concerning the action of the chamber when the point is negative. The production of the ionization current has been explained by means of the release from the point of electrons which alone are capable of ionizing the gas. Since this is an exponential process the initial stimulus need be very small; that is, only a few electrons need be liberated so that the counter should count an α-particle as soon as it has entered. Furthermore, the disturbance should soon die out since the electrons will soon reach the chamber walls, after which no new ions will be produced in the chamber. Because the electrons from the point are responsible for the major part of the total ionization, and these electrons produce ions each time in the same region of the chamber for each α-particle counted, we expect the total ionization current for a given set of conditions to be approximately the same for each α-particle which is counted. In all these respects our explanation is consistent with the known behavior of the counter when the point is negative. It therefore seems reasonable to assume that some such process as outlined actually goes on in the layer of adsorbed gas when the point is in the sensitive condition to enable the electrons to escape.

We now turn our attention to the operation of the chamber when the point is positive. The counter has been used in this way only rarely and has not apparently given satisfactory results in all cases when thus tried. However, the writer has found, in agreement with one or two other observers, that the chamber works well this way at about the same voltage as when reversed. The further interesting observation has been made that the *nature of the surface* of the point is immaterial for the operation of

the counter when the point is positive. If a point of a given sharpness has the proper voltage applied it works regardless of the kind of metal or its treatment. This observation shows that adsorbed gas or catalysis can play no part in the action of the point when positive. This conclusion is further substantiated by attempts to "poison" points when operating at positive voltages. None of the catalytic poisons produced any effect. This is not very surprising when we realize that when the counter is used in this way we no longer need to release electrons from the point since they are already traveling toward it. We can now visualize the process of producing the ionization current for each α-particle entering, as follows: When the α-particle enters it produces as before a few pairs of ions. The positive ions go to the chamber walls. Since they have low mobility and are in the weakest part of the electric field when they arrive at the walls, it is scarcely conceivable that they can do more than be collected. The distribution of the electric field with the point negative is of course very similar to that when positive, as is shown by the diagram in Fig. 5. The region of rapid change of potential is still near the point and we may say that practically all the ionization current is produced in both cases in some such region as A and little or no new ions are produced by impact in the region B in each case. When the point is negative, electrons cease to ionize by impact after leaving the region of A since they are no longer accelerated enough between collisions to acquire the necessary kinetic energy. Turning to the case of the positive point we find that a few electrons are produced as part of the primary ionization by the α-particle on entering some part of the region B. These move toward the point and as soon as they reach the region A they begin to ionize by impact, since they are now in a strong enough field so that between each impact they acquire enough kinetic energy to ionize at the next impact. We now have a condition almost identical with that existing when the point is negative and a few electrons have been released from it. The ionization current builds up exponentially and the disturbance rushes rapidly to the point, the current being produced in the

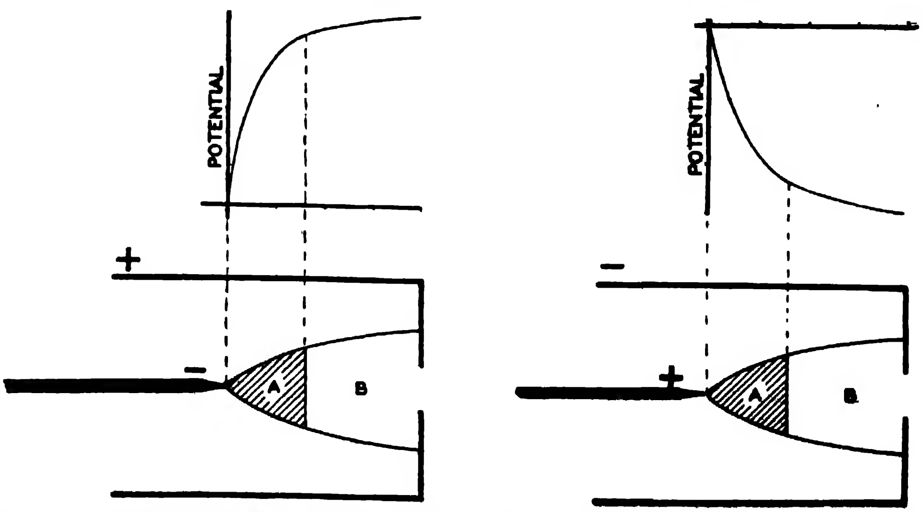


FIG. 5. A DIAGRAM COMPARING THE VARIATION OF POTENTIAL WITHIN THE ION COUNTER, WHEN THE POINT IS NEGATIVE, WITH THAT WHEN POINT IS POSITIVE.

same volume of the counter as when the point was negative. About the only difference between the two processes is that they travel in opposite directions. It is now easy to see also why this current at once ceases when the disturbance reaches the point. All the electrons are moving rapidly to the point while only the positive ions travel through the gas between this disturbance and the chamber walls. But these, as we have repeatedly mentioned, can not produce new ions by impact. Hence there is no means provided to produce a further supply of electrons in the rear of the disturbance as it moves to the point and the current dies out at once. The only way this current can be again started is by producing a few electrons in the B region of the counter, as, for example, by the entrance of another α-particle. This of course is just the condition which must obtain for the chamber to count successfully. Consequently it now seems to be clear why the counter behaves much the same on reversed potential, although in one case the nature of the surface of the point is so important and in the other it plays no part.

Additional work is, of course, required to further perfect the counter, making use of the information now available. Since there are certain advantages in working with the chamber when the point is negative it appears worth while to determine what conditions are really most favorable from the standpoint of sensitivity and permanence. For example, further study may show that the deterioration of negative points may be the result of slow catalytic poisoning from traces of SO_2 in the laboratory and that points may be made permanent by using only pure gases in the chamber. By such investigations one may hope to secure further improvement in the counter so that it may become more reliable. There is also the possibility that the counter may be used in studying catalytic substances or controlling the preparation of catalytic materials in industrial processes. Hence, this work may have a by-product of some practical value.

THE INTERPRETATION OF RESEARCH

By Dr. BENJAMIN T. BROOKS

NEW YORK, N. Y.

If Mr. Chesterton had ever been interested in scientific research he undoubtedly would have observed that the only enemies of scientific research are some of its friends. Research must usually be interpreted. The world at large, and particularly the business man interested in technical progress, and the youth, who may be groping about for a career, is entitled to know what is happening and what are the trends of research and its significance. The world is entitled to reliable information as to what is going on in our scientific laboratories. The average business man is convinced of the value of research, but the miracles of research, both real and imaginary, have been featured so much in the public press that, in the game of selling stocks and promoting fraudulent enterprises, mystery processes and chemical hocus-pocus play very much the same rôle in getting the public's money as mining stocks did in an earlier generation. Unfortunately, some scientific men are so imbued with the idea of "selling" research that they have contributed not a little to the success of those who are more frankly dishonest. The bad effects of lurid exaggeration and carelessness in the writings and public addresses of scientific men and others who attempt to interpret scientific work have become so evident that it is worth while to inquire whether the "selling" of research by the methods of modern high power salesmanship and advertising is not doing more harm than good.

Reference has been made to the evil results of casting science in the form of Hollywood scenarios. The following is the comment of Mr. Henry L. Doherty, given at the Williamstown Conference in 1926:

> The tendency of the day, however, is to get away from the thought that improvement is apt to come only from long work, conscientiously done and intelligently planned. We are flippantly told that research work aimed to secure minor improvements is not worth while and the man who is most readily accepted to the public as a scientist is the one with a mind best adapted to the occupation of a theatrical "press agent" who tells us that someone is about to "unlock the atom" and unloose energy without limit upon a world composed largely of old-fashioned scientists who have not learned and never will learn to work according to advanced ideas. It is apparent to every man properly trained along scientific lines that, regardless of what may or may not yet be discovered, such persons have no idea of what they are talking about, but the question is—did the originator of this, or other similar sayings, have even a definite dream in his mind, and if he did we would all like to know about it.
>
> It may be urged that it is no part of the activities of scientists either to reprimand or fight other people, but I hold it is the duty of every real scientist to reprimand and rebuke those who may make scientists appear impractical or ridiculous or who are an obstacle to the progress of science, and everybody who predicts some accomplishment to which he can not point to a proper reason therefor is an enemy to the progress of science and only by reprimand and rebuke can this damaging talk be stopped. I have been told at least a hundred times in the last four years that there is no reason to worry about the future of our oil supply, for science will surely find a substitute for petroleum. *I am sorry to say that some of the men who have said this have been classed by the world as scientists*, but most of them are without scientific knowledge of any sort and none of them have as yet been able to offer any evidence that they have the slightest knowledge which might justify such a statement.

The interpretation of scientific research is an exceedingly difficult matter. There are few men who can write with

the inspirational quality, beauty of diction and scientific soundness of Tyndall or Robert Kennedy Duncan, few such lecturers as Millikan and few busy investigators who will take the pains to put science into simple language filled with philosophic meaning, as Paul Heyl has done. But, apparently, there are people who believe that the "tabloid" newspapers should have "tabloid" science, phrased in the "peppy" sentences of Mr. Babbitt. Apparently, some believe that selling science is like selling religion and saving souls; probably the percentage of those who remain converted is the same in both cases. Some of the chromatic magazine covers, devoted to science and invention, suggest all the thrill and melodrama that Frank Merriwell and Nick Carter formerly supplied. Must morons be supplied with moron science? It would be more dignified and effective if we were to advertise in the subway with placards: "Patronize Your Neighborhood Research Chemist" and put up billboards in the country stating "Research Brings Business Health," or "Wealth from Atoms," embellished by a pink bathing beauty scrutinizing a test tube. Dignified slogans could be used, such as "Research Reaps Rich Rewards."

There can hardly be any question but that careless, bombastic or exaggerated interpretation of science does a great deal of harm. Not long ago the writer was discussing a public address recently delivered by an officer of one of our largest technical societies. The address in question was a romantic phantasy of what wonderful things were going to happen as a result of a certain line of research (if only some one would come forward and put up the money for said research). My friend said: "I recognize the applesauce you are talking about and its author, but what harm does it do? Nobody takes that sort of thing seriously. He is accustomed to dealing with young students who must be inspired by pretty fancies so that they will try things. Other people, in the full possession of their faculties and whose time is valuable, would never dream of trying such things." Aside from the question as to whether such romancing is good pedagogy, it is not intended as fiction and is therefore *not honest*. With the exception of a few fundamentalists the world has come to believe that the essence of the search for scientific truth is honesty, and any one who has won recognition as an investigator comes before the public forum with this badge of the guild stamped upon him. What is going to be the feeling of the business man who has sunk money in ill-considered research, if he is told that public addresses should not be taken seriously, that this is just one way of selling research, just the big noise outside the tent? What is going to be the feeling of the student, whose time is taken during the arduous years of his technical training, when he discovers that his research director was only using him as a pawn in the effort to achieve a little sensational publicity, that the research on which his time was used was scientifically unsound or foredoomed to failure as to industrial usefulness by economic facts.

It is true that a great deal of money has been made and is being made by scientific research. Research is scientific exploration. Research is the one kind of speculation which is absolutely essential to technical progress. But there is another side to the picture. A great deal of money is lost in ill-advised unsound research and in research conducted by incompetent investigators. Perhaps it is a kind of heresy to mention these facts. It is true that it is difficult to judge the unknown. It is difficult or impossible to estimate the chances of success with any accuracy. But an honest attempt can be made to make an "estimate of the situation," as the student of military opera-

tions phrases it, first with respect to the economic limitations and second as to the scientific soundness of the project. The story is told of Professor Adolph von Baeyer, the grand old man of organic chemistry, that a research student suggested that he be allowed to take up the synthesis of quinine so that it could be manufactured instead of extracting it from Peruvian or Ceylon cinchona. A good idea, but the old master is said to have replied: "Young man, you will not live long enough." Quinine undoubtedly will be synthesized in the course of the march of chemical research, and perhaps manufactured cheaper than the natural product. But Baeyer, the greatest organic chemist of his time, did not consider it a good bet.

There has been considerable discussion among scientific men in recent years regarding the question of professional ethics of expert witnesses called to testify in cases before the courts. The general result of this discussion has disclosed the fact that, save for a very few flagrant cases, the standard of professional conduct has been above reproach. The exceptions are very difficult to deal with except by general condemnation by the scientific fraternity. The "selling" of research by gross exaggeration is no less reprehensible and has more far-reaching evil effects than perjury by an expert witness. The only way to stop the selling of scientific research by public utterances resembling the tooting of a steam calliope is by the vigorous disapproval of scientific men themselves. This is not so easy or as certain of results as it sounds. University trustees have been known to promote the professor who rushes to the public with visions of driving vessels across the ocean by releasing the electronic energy of a thimble full of matter. Just what kind of matter or just how the energy is to be released and applied are, of course, details that are *omitted in the rush for publication. So long as* trustees desire this type of professor one can not be surprised if there are a few professors willing to supply the demand. There has been a genuine desire shown by the best of our public press to keep the scientific quack and charlatan out of its columns, but every newspaper loves a sensation and only the best of them hope that the sensations which they print are all true. The American Chemical Society has been holding a series of special summer meetings given over to round-table discussion of research subjects, an altogether pleasant and worth-while series of meetings. But there is always at least one jack-in-the-box, who must jump up, if only to say something which the late afternoon press will feature with the baseball scores. At the recent Evanston meeting armies were anesthetized by chloroform, chemical warfare gases were destroyed by peroxides, and thousands of tons of synthetic rubber were made from the waste gases of petroleum refineries, all in one afternoon. Nobody wishes to suppress such discussions, but since newspaper men look very much like other people, externally, they invariably find a way in, and a good reporter can smell a sensation as far away as a camel can smell water. There is always a great deal of difficulty with censors; they are as popular as baseball umpires. The only practical remedy is for scientific men to be more careful of their *public* utterances.

Another reason for some of the vigorous optimism of some of our popular science lecturers and writers is the rather large amount of money which is spent upon research. Competent research men certainly are not paid too well, but they are generally much better paid than many other classes. The director of one of our best known and most successful industrial research lab-

oratories recently told the writer that in his experience only about twenty out of every one hundred Ph.D. men given temporary employment with his company were sufficiently competent to be considered for longer employment. What happens to the researches that the incompetent 80 per cent. undertake for other companies? How many of them continue to take advantage of the widespread and liberal financial support of scientific research, only to make a living, until their employers become disgusted or lose their money? Of course, all such matters adjust themselves in time, but often with a good deal of disappointment all around. Ill-considered, unsound research propaganda leads to the employment of many incompetent persons on unsound research projects; the employer loses not only his money but his patience and his faith in scientific research as an aid to his business.

It may be worth while to illustrate the different methods of soliciting financial support of research by considering the case of synthetic rubber. It is not necessary to go into technical details. Let us remember that at the International Congress of Applied Chemistry held in New York in 1912, Dr. Duisberg, one of the directors of the famous Radische Co., exhibited an automobile tire made of synthetic rubber. The conversion of certain very reactive hydrocarbons, such as isoprene, into rubber-like material has been an accomplished fact of scientific interest for about twenty years. The rubber-like material produced in the laboratory has never been equal to natural rubber in quality, and rubber chemists who have studied the matter intensively for many years can give many reasons for this difference. But assuming that research and skill will in time bridge this gap, the real problem consists in finding a source of the raw material, isoprene, which will be substantially cheaper than the cost of producing natural rubber on the Indo-Malay plantations, where it can be produced for about twenty-five cents per pound. If a satisfactory synthetic rubber could be manufactured at a cost only a little greater than this figure we might then have a situation like the case of natural camphor and the synthetic product, made from spirits of turpentine; the synthetic product serves as a check on the price at which natural camphor, a monopolized article, may be sold. No one questions the importance of rubber in our present industrial scheme of things. Our American requirement is something like seventy-five to eighty million pounds per month.

Let us suppose that both A and B are optimistic research chemists and that both need money equally badly. A represents the matter to a business client something as follows: "There is nothing really difficult about the commercial synthesis of rubber. In fact I have made a specimen recently from petroleum, which you may examine. All I have to do is to improve the yields somewhat and it will be a commercial proposition. A billion pounds of synthetic rubber per year will be an enormous business, which will make an equally enormous fortune for somebody, and the manufacturer who develops this business will earn the undying gratitude of the nation for making us independent of the natural supply. All this problem needs is a little intelligent, optimistic research. Rubber is a hydrocarbon; petroleum is a mixture of hydrocarbons and all we have to do is to convert the one into the other by processes which are to a large degree already known and understood, etc., etc."

B states the case about as follows: "This is an attractive problem from a scientific standpoint. However, I would suggest that we make a preliminary investigation along several lines. We should find out what the situation is

with respect to plantation rubber, whether improvements have been made or more extensive areas planted, which may materially lower the cost of producing natural rubber. It will also be of interest to find out whether manufacturers of rubber articles can utilize a substantial tonnage of synthetic rubber of the quality which the researches of the last twenty years have shown can be produced, provided we solve the problem of a satisfactory raw material. What special markets exist for inferior rubbers, and would it be possible to improve upon the natural product? Would you be willing to meet the budget of such a research for a period of at least five years? It is my opinion that the problem is a difficult one and several very able men should be employed. The annual expense would be about .... thousands of dollars. Petroleum has frequently been suggested as a suitable raw material. Prior investigators have of course not overlooked this possibility and beginning with Engler and Staudinger in 1910 the results to date have been about so and so. It is possible that many so-called by-products may have to be utilized, if we use petroleum, and this may make it possible for you to get your money back even if we do not succeed in making synthetic rubber, itself, commercially. We shall certainly discover many things of scientific value and interest in the course of our work, which will make it worth our while, as scientists, but we can not guarantee you financial returns with the same degree of certainty. If, having given you the scientific aspect of the problem as best I can, and after studying its economic aspects, you believe, as I do, that it is a good speculation, then 'Here is how.' "

The case for theoretical research without any specific industrial objective is quite another matter. The director of a well-known industrial research laboratory told the writer recently that every purely theoretical discovery made in their laboratories had found an industrial application within two years of the discovery. But selling theoretical research is rather too difficult for the popular writer and is seldom attempted. Professor Pupin has told of the great effect that Tyndall's lectures in this country in the seventies had upon the popular support of theoretical research. Even this great cause suffers at times from the zealous exaggerator. He would balance a great industry upon the point of a single theoretical discovery. But, as Robert Kennedy Duncan phrased it, many great problems are solved by the organized attack of a veritable army and the methods of advance are comparable to the slow fighting and advance of a siege. The cancer problem is such a one, and the final solution, when it comes, will rest upon an enormous foundation of painstaking research by a host of workers.

Many of those who undertake to interpret research or seek to dazzle with their prophecy are probably the counterpart in science of those who, in the field of art, seek to gain fame by painting cubist pictures, writing free verse or dissonant music. Unwilling or unable to learn the technique of their art or of science, they leap to the stage and pose as true prophets of the future.

Undoubtedly the greatest good that can result from the proper interpretation of science is the inspiration of youth with the ideals of science and zeal for research. One of our most gifted interpreters of research recently gave an address on "Carbon," which dealt first with soot, carbon black, coal, then with the diamond and finally with the daring objectives of modern organic chemistry. He explained to me that he believed all elementary students should be occasionally led to the mountain top, to a high point of vision so that they might see all the beauty and supreme importance of

scientific endeavor and he stated that at the same time it should be explained to them that only by a great deal of hard work could they fit themselves to participate in the glory of the great achievements. One of the finest and most daring examples of inspirational teaching that has come to the writer's notice is being made at one of our state universities of the Middle West;[1] the students of general chemistry are given a series of ten lectures on the nature of matter, including the essential facts so far discovered of the structure of atoms, something of stellar evolution and the explanation of stars of abnormal densities, atomic disintegration, the space lattice of crystals, and the like. Five special lecturers, including a professor of physical chemistry, a professor of astronomy and a professor of mineralogy, put their best effort into these lectures. Such interpretation of science is an art, and, like all great art, it is extremely hard work. If there should be any question as to whether such teaching is effective, a recent statement of Dr. W. R. Whitney, director of research of the General Electric Company, gives the answer. Dr. Whitney stated that in over thirty years he had "never known a good, able man to come from a poor teacher."

In conclusion, it may be worth while to consider the general reader a little. The cultural value of scientific education has never been appreciated as it is at the present time. Since the radio is in nearly every home, who has not heard of electrons? Who has not heard of vitamins, insulin and perhaps even the cosmic ray? There is a large proportion of the reading public that is seeking information regarding scientific subjects, and they are entitled to serious consideration. A mathematical physicist once told the writer that there were probably less than a dozen men in America who could read the mathematical papers of James Clerk Maxwell and understand them, and the same probably applies to the publications of the famous physical chemist, Willard Gibbs. While these examples are somewhat extreme, there is no question of the need for adequate translation of science, from the language of mathematics, physics and chemistry into English. Interpretation means more than making the facts intelligible; we wish to know what it all *means*, what scientific discovery is doing to our philosophy and our mental life, as well as the world of fact and our prospect of health and happiness. Professor Michael Pupin's "The New Reformation" and Dr. Arthur S. Eddington's "Stars and Atoms" may not be among the best sellers and may not have placed these authors on a popular lecture circuit, but their interpretation of science is in the spirit of the highest scientific ideals.

[1] Ohio State University.

HUMANIZING GEOLOGY

By Dr. CHAS. N. GOULD

OKLAHOMA GEOLOGICAL SURVEY

In Oklahoma we are now placing the guide-book by the side of the road.

The Lions Club of the thriving little city of Ardmore, aided by the Ardmore Geological Society, has placed by the side of the new highway north of the city a dozen signboards descriptive of the various geological formations exposed on the surface in the Arbuckle Mountains.

The Arbuckle Mountains[1] of southern Oklahoma are an object lesson in geology. Those who know tell us that in no single area of similar size in the United States are there so many geological features as in this region. With the exception of glacial phenomena and volcanic phenomena, almost the entire gamut of geology may be observed in these mountains.

To go a long way back toward the beginnings of geologic history, in far-off Cambrian times, the area where the Arbuckles are now located was a shallow sea. The first rocks deposited in this sea and the oldest stratified rocks in Oklahoma were sandstones and arkoses washed in from some nearby land. This is the Reagan sandstone. The sea gradually deepened and for long eons limestone was deposited, one layer after another, until a total thickness of about eight thousand feet of limestone had been formed. This is the Arbuckle limestone, a great series of massive ledges, one of the thickest limestone formations found anywhere in America.

After the deposition of this massive limestone, the land again rose and a formation fifteen hundred feet thick was deposited. This is the Simpson formation, composed of sandstones, shales and thin limestones. At several places in Oklahoma the sands of the Simpson formation are quarried for glass sand, while in other parts of Oklahoma this sand is called the "Wilcox" oil sand. In the Seminole oil field, during the last year, this sand, which is encountered in wells more than four thousand feet beneath the surface, has produced as much as five hundred thousand barrels of oil per day. Other members of the Simpson formation are Burgen sandstone and Tyner shale.

Lying above the Simpson is the Viola limestone, eight hundred feet thick; then, in ascending order, are the formations known as the Chimneyhill limestone, Henryhouse shale, Haragan marl, Bois d'Arc limestone, Woodford chert and Sycamore limestone. The total combined thickness of the various formations is about twelve thousand feet.

All these formations were deposited during lower Paleozoic time; the Reagan is Cambrian in age; the Arbuckle is Ozarkian and Canadian; the Simpson and Viola are Ordovician; the Sylvan, Chimneyhill and Henryhouse are Silurian; the Haragan and Bois d'Arc are Devonian; while the Woodford and Sycamore are Mississippian in age. There are in the series many erosional unconformities, representing times during which the area doubtless stood above the ocean, when erosion cut away exist-

[1] The Arbuckle Mountains were named from Fort Arbuckle, which was located near the west end of the mountains. The fort was named from General Matthew Arbuckle of the United States Army.

"WHITE MOUND" IN THE ARBUCKLE MOUNTAINS
FROM WHICH MYRIADS OF FOSSILS HAVE BEEN OBTAINED.

A LEDGE OF WEATHERED LIMESTONE
STANDING ON EDGE IN THE ARBUCKLE MOUNTAINS.

TURNER FALLS

NOTE THE CLIFFS OF TRAVERTINE ON BOTH SIDES OF THE FALLS. VIEW TAKEN IN LATE SUMMER TIME WHEN AMOUNT OF WATER WAS LOW.

FOLDED AND TWISTED ROCKS

ing land masses, and no deposits were laid down.

At the close of the period of deposition just described, which extended over many million years, there came a period of orogeny, or mountain making. Great stresses and strains were set up, which compressed or squeezed together the rocks. The entire area now occupied by the Arbuckle Mountains was uplifted like a gigantic blister sixty miles in length, and the rocks which were originally deposited as level-lying sediments in the various Paleozoic seas, were uplifted and tilted so that near the periphery of the range the various ledges now stand on edge, often at an angle of 90 degrees from their original position.

After the elevation of the mountains, erosion at once began to cut down the rocks, and carry the débris into the ocean. This process is still in operation.

Geologists who have studied the matter are not entirely agreed as to whether the elevation of the Arbuckle Mountains took place in a comparatively short period of time, so that the mountains once stood more than two miles above their present level, or whether the uplift was accomplished so slowly that erosion about kept pace with the elevation of the rocks. Whichever method obtained, the fact remains that at the present time the mountains as a whole have been planed down until the general surface consists of a comparatively level plateau, lying at an elevation of about four hundred feet above the level of the surrounding country.

Streams taking their rise in this plateau and flowing toward the north have eroded canyons, and at the place where these streams have cut their way across the upturned ledges of the hard limestones one finds many beautiful waterfalls.

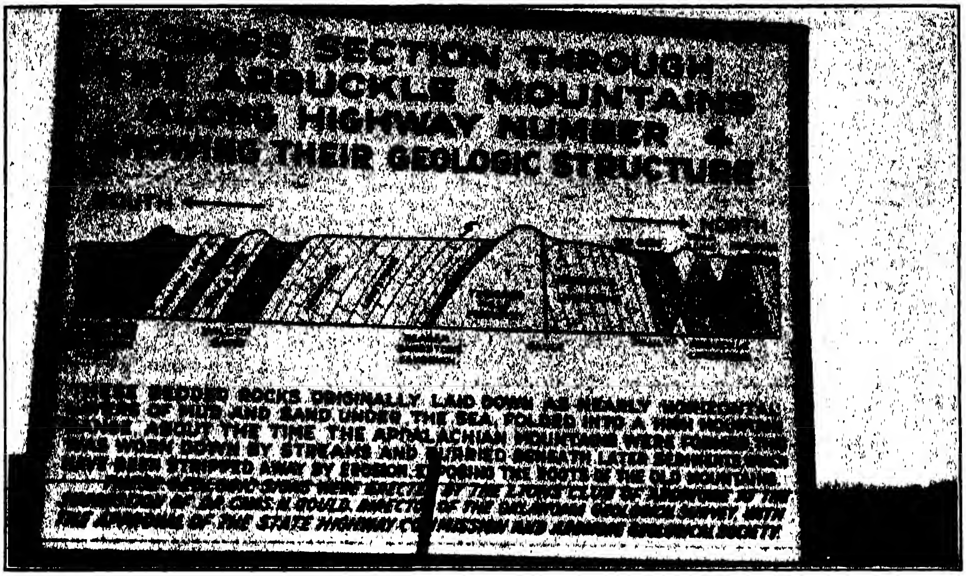
GEOLOGISTS AT WORK

IN THE FIELD IN THE ARBUCKLE MOUNTAINS

United States Highway No. 77 crosses the Arbuckle Mountains north of Ardmore. This is one of the main arteries of travel north and south across the states of the Great Plains. The days of the covered wagon and the deep-rutted roads are over, and to-day hard-surfaced highways checkerboard Oklahoma. The

COLLECTING FOSSILS

FROM PENNSYLVANIAN, TWO MILES NORTH OF ARDMORE, JUNE 27, 1927. LEFT TO RIGHT: DRS. C. E. DECKER, C. W. TOMLINSON, H. D. MISER, C. L. COOPER.



DIAGRAMMATIC CROSS-SECTION OF THE ARBUCKLE MOUNTAINS.

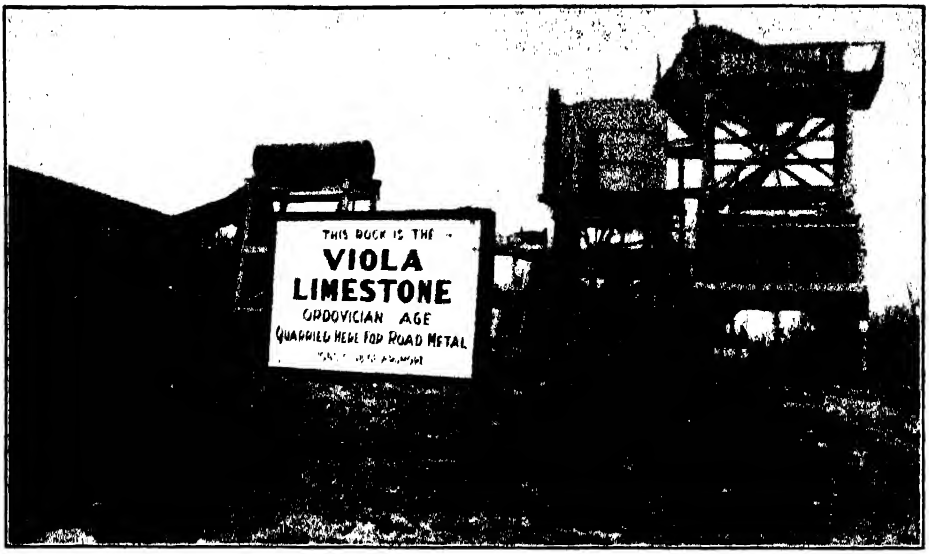
Arbuckle Mountains, extending east and west, interposed their bulk across the main line of communication from north to south. The Santa Fé railroad detoured several miles to the east and found a water gap at the place where the Washita River had sawed its way downward through the heavy limestones. But the highway, seeking a shorter course, climbs the Arbuckle Mountains and runs for six miles along their crest. Thousands of cars daily travel this highway.

It is along this highway where the grade winds down the south side of the Arbuckle Mountains that the guide-book signs have been placed, calling attention to the various formations crossed by the highway. And surely no better place could have been found. In grading the road across the mountains, it was found necessary to blast away many of the ledges, laying bare exposures of rock not previously seen.

In Oklahoma, geology is no longer a strange thing. The people of the state do not look upon geologists as either pedants, freaks or soothsayers. Geology has to-day taken its place among the professions, the same as engineering, law or medicine. In Oklahoma nearly one thousand men follow the profession of geology.

At the State University at Norman, ninety miles north of the Arbuckle Mountains, a geological faculty of fifteen men instructs over thirteen hundred young people. Practically every large city in the state has its geological society. It is largely due to the labors and investigations of these men that Oklahoma to-day ranks second among the states of the Union in new mineral wealth per year. It is the geologist who has been largely responsible for the discovery of the three hundred oil fields of the state, that last year produced petroleum products valued at approximately $500,000,000.

And it is in the Arbuckle Mountains that many of these geologists first received their early training. For many years it has been the custom to conduct field parties from the State University

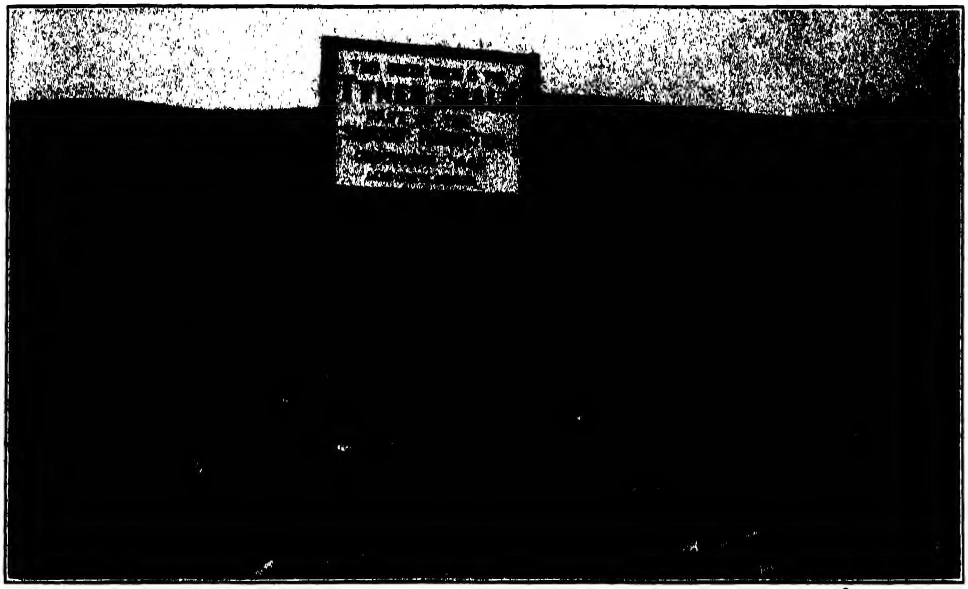


AN OUTCROP OF THE VIOLA LIMESTONE
IN THE ARBUCKLE MOUNTAINS.

and from other schools in Oklahoma and adjoining states into the Arbuckle Mountains. It has been estimated that during the past two decades five thousand young people have studied formations and collected fossils in these mountains.

So that it was the logical thing for the Geological Society of Ardmore to stand sponsor for the idea of labeling the rock formations of the mountains along the newly constructed highway near their city.

AN OUTCROP OF SIMPSON FORMATION



AN OUTCROP OF THE TYNER SHALE
PART OF THE SIMPSON FORMATION.

The moving spirits in the matter were the writer and Dr. C. W. Tomlinson, a graduate of the University of Wisconsin and the University of Chicago, who is practicing his profession as geologist for one of the petroleum companies operating in Oklahoma. He is also a member of the Lions Club of Ardmore. Some two years ago Dr. Tomlinson began to agitate the matter, and succeeded in interesting the members of the Lions Club in financing the undertaking.

Soon after the completion of the highway the signs were erected by the roadside. Eleven of these signs, each describing a single formation, are four by five feet in size, substantially placed, and should last for many years. The largest sign, located on the highest point along the highway, is eight by twelve feet in size and contains a diagrammatic cross-section of the Arbuckle Mountains.

In true western style every one cooperated. While Dr. Tomlinson led off and the Ardmore Lions Club stood sponsor for the finances, other agencies contributed in various ways. The Chamber of Commerce and the Ardmore Geological Society gave assistance. The State Highway Commission varied an established rule and gave permission for the erection of the signs on the right-of-way.

And the people use the signs. It is no uncommon thing to see half a dozen cars lined up by the roadside and the tourists studying the cross-section and reading the description. In distant states one hears remarks anent the geological signs in the Arbuckle Mountains at Ardmore.

The effect is good. The guide-book is by the roadside. He who runs may read, and as he reads the descriptions on the signs and studies the rocks to which the signs refer, he gets an idea of what it is all about.

Thus, in Oklahoma, we are humanizing geology.

AMERICA'S CORN CROP AND THE CORN BORER

By Dr. W. H. LARRIMER

BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE

AMONG notorious insects which have received the wide-eyed attention of the public probably the European corn borer heads the list. Scientists and others who had been in touch with the corn borer situation realized that farmers were confronted by a dangerous insect, indeed one that might threaten the $2,000,000,000 corn crop, but to the majority it took the ruin of the Canadian fields to fully arouse them to the destructive possibilities of the corn borer. Of this destruction in Canada, Professor Lawson Caesar, provincial entomologist, Ontario, Canada, writes:[1]

> A severely infested corn field such as was common in Essex and Kent in 1925 and 1926 before the Corn Borer Act came into force is a sickening sight. Such fields often have from twenty to fifty borers on an average to every plant. The result is that almost every tassel is off; nearly all the leaves have fallen or are hanging down close to the stalk; the stalks in many cases have fallen down and formed a tangled mass, or, if still standing, are bare and brown. The result is that the whole field looks somewhat like a spruce forest after a fire has run over it. Any one who has seen such a field will not doubt the power of the borer, if not controlled, to destroy the corn industry.

Such a failure of the corn crop over 1,200 square miles in Ontario aroused immediate action in the United States and, in the spring of 1927, Congress provided for the most colossal plant protection movement ever launched, the $10,000,000 corn borer clean-up campaign which was undertaken and successfully completed.

There were two important questions for which answers were sought in the large scale clean-up campaign. First, there had been a more or less friendly disagreement with the opinion of the entomologists who doubted that the further spread of the corn borer could be prevented. Second, the entomologists and others were alike interested to know whether the corn borer could be controlled. The "Clean-up Campaign" answered these two questions; first, the borer will continue to spread to new territory in spite of everything that can be done; second, the numbers can be kept low enough to prevent serious commercial damage by the clean-up methods so well advertised by the campaign. As the corn borer advances into the great corn belt, the problem therefore becomes one of controlling it by a thorough and concerted clean-up of all the previous year's corn remnants before June 1, and prevention of long distance spread by maintaining a strict quarantine of the infested area.

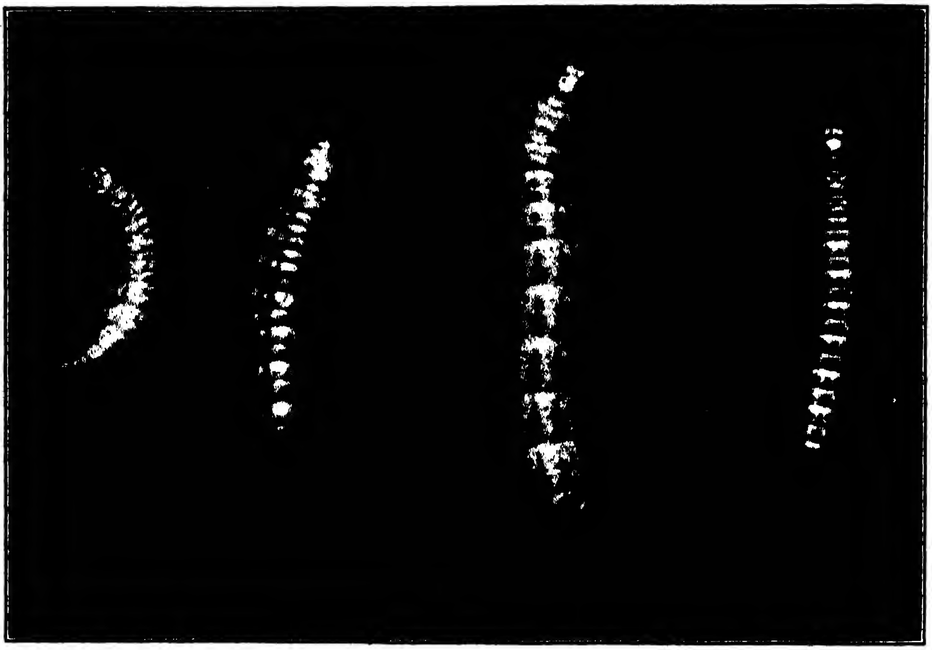
The corn borer was introduced into this country probably about 1910 in shipments of broom corn from southern Europe. As this was before the Plant Quarantine Act of August 20, 1912, the borer had a good chance to get in and develop undisturbed. The insect was first discovered here in 1917 near Boston, when it was estimated to infest about one hundred square miles of territory. Stewart C. Vinal, of the Massachusetts Agricultural Experiment Station, who discovered the pest, immediately began to study its economic importance and possible methods of

[1] Lawson Caesar, "The European Corn Borer," Bull. No. 334, Ontario Dept. of Agr., Ontario Agr. College.

HEAVILY INFESTED CORN FIELD IN ONTARIO (OCTOBER, 1927)

control. In 1918 the investigation was carried on in cooperation with the U. S. Bureau of Entomology and in 1919 the Federal entomologists took over the work. As the borer steadily advanced and the gravity of the situation became more apparent, the organization was expanded and the problem attacked from all possible angles. At present the research problems are being studied at six Federal laboratories, scattered throughout the infested area of the United States, and one laboratory maintained by the United States in central Europe to study the insect in its native habitat. The search for effective parasites is also being carried on by Federal entomologists in Europe, with the main laboratory at Hyères (Var), France, and in the Orient, with headquarters in Japan. Surveys are conducted each year to determine the spread and the intensity of infestation, while a strict quarantine on infested products is enforced throughout the corn borer area. Many of the infested states have excellent research organizations at work on the corn borer problems and several of the threatened corn belt states are studying the pest in advance of its inevitable entry into their territory. State regulatory forces are doing everything practical to meet the difficult situation presented by the presence of a new pest of such potentiality.

The region now infested with corn borers includes all or parts of thirteen states (map). The western area most important in the spread towards the corn belt includes the southern and eastern sections of Michigan, the northeastern corner of Indiana and the central and northern portions of Ohio. The borer is known to have traveled to within thirty miles of Lake Michigan and probably the scouting now being carried on will reveal the thirty miles bridged and that a zone of infestation has been added around the edge of the present infested area.



THE CATERPILLAR STAGE OF THE EUROPEAN CORN BORER
IT IS IN THIS STAGE THAT THE BORER DOES THE DAMAGE AND ALSO THE STAGE IN WHICH IT CAN BE CONTROLLED BY CLEAN-UP OPERATIONS.

Most of this area, however, is still very lightly attacked, having less than 1 per cent. of the stalks infested; that is, less than one stalk in a hundred contains a borer. The only place where the population has built up sufficiently to cause commercial damage is in a very narrow strip along Lake Erie. It is estimated that between five and ten borers per stalk are required to cause noticeable commercial damage.

The corn borer is a whitish caterpillar with a brownish or often a pinkish tinge. It is about one inch long when full grown, and has a dark brown head and many small brown spots on its body. The young borers, even when very small resemble closely those that are full grown, but are often when about one half inch or a little more in length a good deal darker in color

The caterpillar winters inside pieces of stalk, stubble or ears of corn and sometimes in weeds and other plant material growing close to corn. Its presence can be detected by small entrance holes on the surface. These holes are usually plugged with the castings of the borers. When the stalks, stubble or

ONE OF THE IMPORTED PARASITES OF THE EUROPEAN CORN BORER
A FEMALE OF *Eulimneria crassifemur*. ABOUT FIVE TIMES NATURAL SIZE.

ears are split open, the borers are usually found within.

As soon as warm weather begins in April or May, the borers resume activity although no real feeding takes place. The borer cuts a small circular opening from its tunnel to the surface of the plant in order to provide an exit for the future moth. This opening is usually closed with a thin partition of silk. The borer then retreats into its tunnel to a point near the last feeding or shelter place, where it usually spins a thin cocoon in which it changes to the pupal stage. The pupa is shuttle shaped, and varies in color from light brown to dark brown, and in length from one half to five eighths of an inch. After a period of from about ten to fourteen days the skin of the pupa splits and the moth comes forth. In the Great Lakes area the moth is present in the fields during late June, throughout July, and during early August, under average weather conditions.

The moth measures about an inch from tip to tip of the wings and varies in color from pale yellow to light brown. The moths of the corn borer resemble so closely several other kinds of moths that it is almost impossible for the average person to distinguish them. They are strong fliers, experiments having shown them to fly at least twenty miles, and it is very probable that they do fly greater distances. Large bodies of water do not check their flight, for they have been seen to alight on the surface of the water and again take flight. It is probable that moths have flown across Lake Erie in this way. This flight of the moths (like the blowing of the wind, that can not be prevented) results in a natural spread into new territory for distances of between twenty and thirty miles each year.

Soon after emergence the moths mate and begin to lay eggs, each female moth laying an average of 400 eggs. They remain quiet during the day, hiding in patches of weeds and grass or underneath the leaves of other plants. During the early evening and early morning they fly from plant to plant, laying their eggs usually on the under-side of corn leaves.

The eggs hatch in from four to nine days and the little caterpillars soon eat their way into the corn plant where they spend their life, tunneling up and down the stalks into the ears, and unobserved eating out the life of the corn plant. It is at this time that the damage is done.

As is the case with many introduced insects, the corn borer seems to be far more destructive in America than it was in Europe. The reasons for the apparent control in Europe have been given careful study by entomologists from the United States and, as a result, twelve species of parasites preying on corn borers have been imported, bred in the laboratories and liberated in fields infested with corn borers. In bringing these parasites into this country every precaution has been taken to import only insects absolutely harmless to our vegetation. Care has also been taken to leave behind all enemies of these parasites, for they in turn have their parasites.

> So, naturalists observe, a flea
> Has smaller fleas that on him prey;
> And these have smaller still to bite 'em,
> And so proceed *ad infinitum*.—*Swift*.

This parasite introduction has, of course, taken a great deal of time and care, but now more than two million parasites, in which are represented twelve different species, have been liberated at strategic points in the infested area of the United States. Of the twelve species liberated seven have been recovered, proving that they have become established and are at present busily preying upon the corn borer. Help by this method in the control of the

NO CORN BORER SURVIVES A GOOD BURNING

borer will of course be a long process and at present less than 1 per cent. of the borers in the field are being parasitized by these foreign insects.

An effective control of the borer required something giving quicker results. Spraying did not fill the bill, for the borers were inside the plant where they could not be reached during practically all their life. Sprays are known which would kill the eggs, but they are deposited over such a long period of time and are so difficult to reach by the best spraying methods that the number of sprayings necessary would be out of the question. Trap lights, traps and baits were also tried and proved ineffectual.

It was observed early in the corn borer investigations that a certain amount of infestation seemed to be evaded by late planting. However, the agronomists have figured that, because of reduction in yield due to late planting, a 20 per cent. loss from the corn borer must be experienced before it will be profitable to plant corn late enough to evade infestation.

There was, however, one weak spot in the life cycle, the hibernation period, spent during the fall, winter and spring in old corn stalks, stubble and other pieces of corn plant of no use about the farm. Practically all the borers in the field are then in the remnants of the corn crop or débris in the corn field, especially in the Great Lakes area. If all this can be effectively disposed of the borers are destroyed with it.

The surest method of destroying this material is burning. No borer survives a good burning, although it has been known to survive freezing and

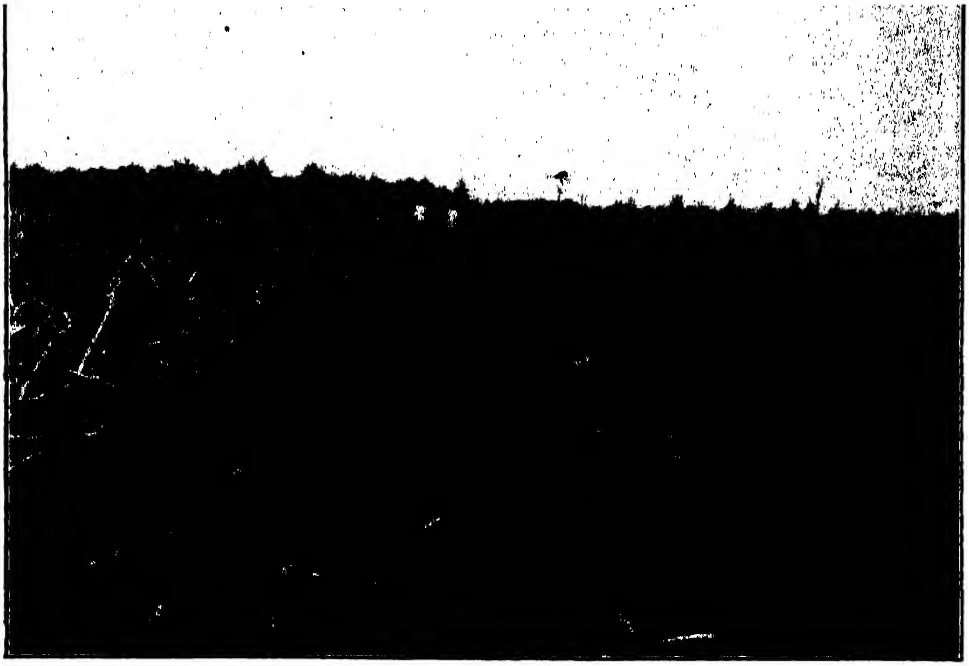
other hardships. If all the old corn stalks, and pieces of corn plant, both in the field and about the barnyard, are thoroughly burned, the corn borer can be controlled.

Gathering and burning in some localities, however, require more labor than is practical and do not fit conveniently into the farm routine. In some cases, plowing all stalks, stubble, and other corn remnants and débris completely under has been found practical and is effective in destroying the borers. The plowing does not kill the borer, as it crawls to the surface after being plowed under, but if it finds no pieces of corn plant or other plant material on the surface in which to take refuge, it will most surely die from exposure, birds or other natural enemies. Experiments have indicated that at least 98 per cent. of the borers in a cleanly plowed field meet their Waterloo. The essential thing in this method of control is absolutely clean plowing, which requires a better than ordinary job of plowing. In plowing for corn borer control, the skill of the plowman is as important as the equipment. Wide-bottom plows are recommended, though a fourteen-inch bottom plow with attachments for covering trash has been found to give satisfactory results.

As the corn borer spreads west over the great corn belt, farmers will have to make the necessary adjustments in their regular farming practices to include corn borer control measures. One efficient piece of equipment in caring for the control problem is the silo. Those that escape death in the silage cutter are killed by the fermentation that occurs in the silo. Those practices which will have to be included in the regular farm routine and that will be adopted by farmers in the wake of the borer are the more general use of the silo, the use of husker shredders, low cutting in harvesting corn, plowing under corn stubble or standing stalks and the feeding, shredding, burning or similar disposal (before June 1 of each year) of all corn débris left around the farm.

One of the encouraging things about the work on this problem of European corn borer control has been the cooperation received from every side. Farm machinery manufacturers have from the first attempted to put on the market equipment suitable for corn borer control and within the reach of the farmer. This effort has produced the sixteen-inch and eighteen-inch bottom plow now on the market, which does a good job of plowing standing cornstalks and stubble completely under. The low cutting attachments for corn binders are now on the market and are being further perfected. These attachments will cut the corn to within two inches of the ground, which is considered satisfactory for corn borer control. Engineers, entomologists and agronomists are now at work on a corn combine which is so designed that it cuts low, picks and husks the ears and cuts or shreds the fodder in such a manner that a high percentage of the corn borers are destroyed. Much is expected of this type of machine as an important factor in corn borer control in the corn belt. There are being developed more efficient rakes for raking up last year's corn débris, portable burners and other pieces of equipment which will lighten the burden of corn borer control for the corn grower.

As previously stated, when the danger to America's corn crop was brought to the attention of the Congress in 1927, $10,000,000 was appropriated for a clean-up campaign to try to check the spread and cut down the increase or possibly reduce the number of borers in heavily infested areas. To make the campaign effective, about 2,500,000 acres of corn had to be cleaned up and more



PLOWING IN STANDING CORN STALKS WITH 18-INCH PLOW (JUNE, 1927)

than 200,000 farmers had to be reached and convinced of the necessity of a thorough clean-up. Every corn field in the campaign area had to be cleaned up and subsequently inspected in order to make the campaign worth while.

The plan of the campaign was to secure, where possible, the voluntary cooperation of the farmers in cleaning up their own fields and for the federal and state officials then to step in and, under state authority, to finish the job for those who either could not or would not do it. For the extra expense incurred by the farmer in cleaning up his fields the Federal Government proposed to reimburse him not to exceed $2 per acre. In some cases, the cost was actually more than this, but $2 per acre was considered a fair compensation in most cases and the appropriation was not sufficient to pay the actual cost in all cases. More than 185,000 farmers took advantage of this opportunity, cleaned up their fields, passed federal inspection and collected their extra labor fee.

Those fields which were not cleaned up by the farmers by May 15 were taken care of by clean-up crews operating under state authority, and the cost assessed against the farmer by adding it to his taxes. In most cases this cost has been assessed against the farmer and the states have collected a large percentage to be returned to the United States Treasury.

In putting on the campaign one of the principal limitations encountered was lack of time. The money became available on March 14, and thus only six weeks were left before it was necessary to start the compulsory clean-up in order to finish it before the moths began to fly in late June. In this period more than 200,000 farmers had to be told of the regulations, advised as to clean-up methods, given opportunity to do the work, and their fields inspected to deter-

mine whether reimbursement should be made. How well this was done can be judged from the fact that 185,000 farmers actually collected for the extra expense incurred.

Owing to extremely unfavorable weather for the clean-up operations and to the retarded development of the borer, the time for voluntary clean-up was extended from May 1 until May 15, when the clean-up crews stepped in and under state authority cleaned up the remaining corn acreage of about 68,000 acres scattered throughout five states.

As a result, entomologists estimate that more than 95 per cent. of the borers were destroyed when the campaign officially came to a close July 1, 1927, at which time borer moths began to emerge that year.

The real test of the success of the campaign, however, came with the fall survey to determine the resultant borer population and spread. It was found that the spread had been retarded very little, as can be seen by the map, largely because it was not practical to secure the clean-up of the border area, but the density of infestation had been kept down and commercial damage avoided.

Having shown the value of clean-up as a control measure and the futility of the best possible clean-up to prevent spread, it seems that corn borer control, which, like the control of other insect pests, is of local benefit, is therefore primarily the responsibility of the states and farmers in the infested area. At the same time it would seem that scouting, quarantine, research and education are activities likely to be of general benefit and, therefore, primarily the responsibility of the Federal Government. With a very admirable spirit of cooperation, such a program, calling for the mutual acceptance of responsibility appropriate to the various organ-

LOW CUTTING

SHOWING THE KNOWN DISTRIBUTION OF THE EUROPEAN CORN BORER IN THE UNITED STATES

izations and individuals, is now in operation.

Though the corn borer is truly a grave menace to corn growers and now seems to be pursuing its inevitable way towards the corn belt, the outlook is not as dark as it first appeared. The clean-up method of control has been proved, by the 1927 campaign, as both effectual and practical in preventing commercial damage. Results of the 1928 clean-up effort show that the farmers are also both willing and able to practice control measures, once they are convinced that such are necessary. In 1928, in the absence of compensation in the areas under regulations, as many farmers cleaned up voluntarily as in the previous year when they received compensation for their extra labor. However, only the more heavily infested areas were included under the clean-up regulations in 1928 and, in most cases, the farmers were familiar with the corn borer and had personally seen evidence of the damage it was capable of doing.

As the borer spreads westward, it will be necessary for the farmers to change the farming routine to include a proper disposal of all old corn stalks, stubble and other remnants of the corn plant before June 1 of each year.

THE INFLUENCE OF ENGINEERING ON CIVILIZATION[1]

By Sir WILLIAM ELLIS, G.B.E., D.Eng.

In choosing the subject for my address I had to decide whether to devote my attention to some branch of engineering in which I have been actively engaged during my working life, alluding specially to some of the technical problems involved, or to treat of engineering in a less technical manner so as to interest any hearers or readers of this address who may not themselves be actively engaged in the engineering profession. Knowing that the Engineering Section would be addressed on technical subjects by very distinguished engineers, I have decided to devote my address to speaking of the very extensive part which engineering in its many branches has taken, and is still taking, in connection with the amenities which are associated so closely with our domestic life, and, indeed, our happiness. I shall hope in the course of my address to deal in some detail with the fact that each branch of engineering has added its quota to the comfort of our lives, and I think it may be claimed that no other profession has so direct an association with our modern civilization. The enormous increase in population during the nineteenth century, coupled with the segregation of that population in industrial centers, arising out of the extraordinarily rapid development of industry in this and other countries during that period, has introduced new problems in connection with health and transport, and it has been the task of engineering in its many branches to deal with these problems. It must be admitted that the great advances made in the knowledge of both medicine and surgery have played a very noble part in connection with improvements we all welcome in the health of the population, and in speaking of the part which engineering has taken in connection with public health I have no wish to lessen in any way what we all admire and respect, namely, the wonderful work of the medical profession in applying for our benefit the constantly advancing scientific and practical knowledge.

In the early part of the nineteenth century main roads did not exist in this country to any great extent, and these roads were in a very inferior condition. Pack horse transport was still in vogue, and up to 1850 a well-organized system of mail coaches was the principal means of passenger transport.

The introduction of railways and of steamers during the first half of that century led the way to an enormously increased demand for coal, iron and steel, and as the inventions of Sir Henry Bessemer and Sir William Siemens for making steel were developed, the necessity was evident to engineers and chemists for training schools to deal with the physical and technical problems involved in engineering and metallurgy, so as to arrive at a far greater accuracy, both in design and construction, than had hitherto been considered necessary or possible. I find on reading the history of those early pioneers, both in engineering and metallurgy, that they had to meet conditions similar to those which exist to-day, that is to say, they had to force their ideas on to a rather unwilling public in order to get them introduced, and in many cases they did not reap the

[1] Address of the president before the Section of Engineering, British Association for the Advancement of Science, Glasgow, September, 1928.

reward of their enterprise. Boulton and Watt had a desperate struggle for their existence. Stephenson had great difficulty in even getting his engine tried amongst those competing for the Liverpool to Manchester railway, and yet was the only successful survivor of the trials. To-day the fate of the inventor is little less hard. In many cases he finds his invention has been anticipated, and in others there is great unwillingness on the part of engineers and metallurgists to adopt the ideas because of the risk involved financially in developing the processes.

We have to admit, however, that the progress of industry depends very largely on the enterprise of deep-thinking men who are ahead of the times in their ideas. I may quote Dr. Clifton Sorby, F.R.S., as such an instance. He introduced by his researches the microscopy of steel, and yet it was many years before this became a recognized method of gauging the quality of all classes of steel. Another great inventor, whom we all respect and are delighted to have still in active work, is Sir Charles Parsons. I look back many years to the early eighties when Sir Charles put in years of research work in connection with high-speed engines before he successfully produced the steam turbine. Since that time he has devoted a large portion of his life to developing improvements both in the design of the turbine and the machinery for producing it, which have ultimately brought about its world renown, and his eminence in the engineering world was suitably recognized two years ago by the award of the Kelvin gold medal.

The technical societies in this country in the latter part of the last century realized that special attention would have to be devoted to an education which would combine a practical knowledge of engineering with a course of technical education of a high level. This was also associated with a preliminary examination to ensure that their students should have a sufficient grounding in general knowledge to enable them to apply themselves with success to the more intricate technical problems incident to their profession. This action on the part of these institutions has been fully rewarded by bringing into existence a body of highly trained engineers with special knowledge of the different branches of engineering, and, therefore, well able to lead our profession forward in the great developments which are still taking place in all branches of engineering.

Although in this address it would be out of place for me to discuss education in detail, I can not help feeling that the ground to be covered in engineering education is now so great that the universities will do well to apply education in general engineering problems for the first two years of a university course, and allow an honors degree to be taken in one or other of the special branches of engineering. I would urge that with the very short terms existing at our universities, in some cases only three terms of eight weeks each, it is unreasonable to expect a student to take an honors degree in three years if this covers all branches of engineering science. The alternative now being considered of meeting the difficulty by taking four years for an honors degree is, I think, open to grave objection, as it is delaying too long the date at which a young engineer is available to take up his first professional appointment and in fact become an earner.

Coming back to my original subject, can we say which branch of engineering has most directly been associated with modern civilization? I do not find that any one branch can claim the premier position. It depends, of course, very much on what we regard as the greatest essentials in life, and I presume we must admit that the greatest happiness of the greatest number must be taken as the

true gauge. In this case some of the luxuries and comforts of modern travel do not hold a primary position, much as we appreciate them. Such questions as purity and sufficiency of water supply for large cities, coupled with a scientific system of drainage, are the first essentials of health and comfort, especially in areas with large populations.

I will now turn to the different branches of engineering and illustrate as far as I can the benefits which these branches of engineering have introduced into the civilization of our present age. In doing so I would refer to the definition of engineering given in the royal charter of the Institution of Civil Engineers on its incorporation in 1828. The centenary of the institution has just been celebrated, and all engineers must be grateful to the principal of Edinburgh University, Sir Alfred Ewing, for the carefully thought out review of engineering progress in the last century, which formed the subject of the James Forrest address at the centenary meeting in June. The charter describes engineering as "a mechanical science dealing with the art of directing the great sources of power in nature for the use and convenience of man." The term "civil engineering" is a comprehensive one embracing all branches of the profession other than military engineering, but I propose to apply the words "civil engineering" in this address as dealing specially with drainage and irrigation works, harbors, docks, reservoirs, etc., dealing with railways under the heading of transport.

The various branches of engineering I propose to allude to shortly in detail are as follows: Civil engineering, as defined above; transport; shipbuilding, including marine engineering; mechanical engineering; mining engineering; electrical engineering.

Civil Engineering

The point which appears to me to stand out prominently in this branch of the profession is the fact that the structures to be dealt with are in many cases of an enormously costly nature, and have to be carried out with such careful study and comprehension of the varying problems to be dealt with so as to ensure permanent efficiency and safety in the future.

The great reservoirs and harbors of the world may be regarded as the cathedrals of engineering. The varying natural problems to be dealt with involve a very high level of technical education. In the construction of reservoirs, docks and harbors a considerable knowledge of geology is essential, and in harbor construction the varying effects of tides which have to be studied minutely have an important influence on the work to be undertaken. Throughout the world will be found monuments to the skill of the civil engineer and the very existence of the population in our large cities in health and comfort is the result of his work, for without an ample and reliable supply of water of good quality, both for personal and industrial use, and an efficient drainage control, our death-rate would indeed be very different from what it is. If we turn for a moment either to India with its great barrage enterprise, or Egypt, with the noble Assouan and Sennaar dams, truly outstanding works of the civil engineer, we find the prosperity of these countries largely resulting from the magnificent irrigation works which have been carried out there. Special development of produce growing in many countries is only being limited by the fact that insufficient irrigation works have so far been carried out. New Mexico and Arizona are two great provinces with potentially fertile land available for agricultural development, but they are so short of water that irrigation is an absolute necessity.

The large increase in tonnage of ocean-going vessels has resulted in the necessity for larger docks and harbor basins, and the development of railways all over

the world, many of them in difficult mountainous countries, has given the civil engineer a great opportunity in designing bridges for carrying this heavy traffic. Many of my audience will appreciate the magnitude of the new bridge over Sydney Harbor now being constructed by British engineers, and the Forth Bridge still holds its own as a masterpiece of British engineering skill, and the construction was in the hands of a Scotch firm well known in Glasgow. The new high-level bridge at Newcastle and the new Mersey tunnel are, I suppose, the most interesting civil engineering works at present in progress of construction in this country, in addition to the considerable dock extensions now proceeding at Southampton, whilst in Canada a very noble bridge is now being thrown across the St. Lawrence River at Montreal.

Transport

It may truthfully be said that the development of the potential wealth of any country depends mainly on the means of transport, both personal and industrial. I would allude especially to the great corn-growing countries, where the home consumption bears only a small relation to the possible production. The knowledge that there is efficient transport both by rail and for export by sea is the greatest incentive to the farmers to spend money in extensive cultivation with the certainty of a ready market for such production. Without mentioning any countries we probably have instances in our minds where inefficiency of transport facilities is absolutely blocking the progress of internal wealth in those countries. On the other hand, where railways are efficient and harbors well equipped with shipping facilities, we find consequent prosperity.

The comparison of travel to-day, both by land and sea, with my early journeys in Europe nearly fifty years ago emphasizes in my mind how much we are indebted to the engineer, in the way of personal safety and comfort and also prompt delivery of our products. A journey in the Balkans in the winter of 1881 when sleeping cars and restaurant cars were almost unknown, and when the largest vessel sailing from Mediterranean ports was in the neighborhood of four thousand tons, compares very unfavorably in speed and personal comfort with the facilities which are available to-day. The comfort and safety of modern travel is to my mind one of the glories of modern civilization. The forty thousand to fifty thousand tons Atlantic liner, embracing as it does almost every class of engineering skill, is not only an example of artistic beauty, but is one of the finest instances of human power combating the forces of nature. To be on one of these vessels driving into a gale at twenty knots is an experience never to be forgotten, and we are glad to realize what a large share the shipbuilding firms of Glasgow have had in the development of these large Atlantic liners.

Railway transport has also made great progress in all measures affecting personal safety and the efficient carrying of our various products. The railway engineers have every reason to be proud of their management of the complex organization represented by the great railway systems all over the world. We are personally much safer traveling in an express train than we are crossing the streets of a great city, and I think we may justly be satisfied by the fact that in no country do the railways afford more comfortable or more rapid traveling facilities than in our own. The railway engineer has still some very interesting problems to face. Heavier and more powerful locomotives are the natural outcome of the demand for heavier freight trains. The civil engineer of a railway company can not deal with this problem without strengthening bridges and improving the condition of the

permanent way. All these developments involve large capital expenditure, which it is not convenient for many railway companies to undertake at the present time.

The question of the railway companies developing motor services to meet the competition of road transport has been the subject of legislation during the present year. I think the public acquiesce generally in the feeling that as the railway companies pay such a large proportion of the rates of the districts through which they have traveling facilities, it is only right they should develop road transport in connection with their traffic in view of the serious competition which they have to face. Transport by road has undoubtedly been very much facilitated by the large sums which the Ministry of Transport has had available for the purpose of remaking and generally improving our main roads, and careful study has been devoted of late years to the selection of suitable materials for this purpose. Consequently, in the last ten years there has been an immense improvement in the quality and design of our main roads, more so than in any previous decade.

It appears to me that one question which has hardly been touched to any extent at present is the desirability of increasing very largely the number of by-pass roads to divert heavy traffic from passing through large towns, and even villages, which are now suffering severely from congestion of traffic in their altogether too narrow thoroughfares.

On looking back a few years to the old system of horse-drawn tramways, we must surely be grateful for the benefit accruing to many thousands of our working population arising out of the introduction of electric tramways, enabling them to live in many cases in much healthier surroundings.

Naval Architecture

This comprises shipbuilding and marine engineering and represents a very important part of my subject, dealing, as it does, with the transport by sea and lakes of food and materials, and with the comfort and safety of the many thousands of passengers traveling to and from this country. The wooden vessel in the early part of last century held its own very stubbornly against the introduction of iron or steel vessels, and the mechanically propelled vessel had to fight very hard to oust the very efficient sailing vessels which were then carrying the trade of the world. I imagine that some of my audience with artistic tastes will not be willing to admit that the beauty of the present type of mechanically propelled vessel is comparable with the picturesque five- and six-mast sailing vessels which we used to see in our earlier days. This country has undoubtedly been the pioneer in the building of large warships and passenger liners, also in the development of the very large horse-power therefor. The considerable increase in the tonnage of ships brought with it the necessity for a corresponding increase in the mechanical appliances in connection with their construction. The trial runs carried out before a new ship is taken over by her owners are a severe test of the excellence of workmanship. They are a necessary test to ensure that long voyages of five to six weeks with machinery running continuously at nearly full power can be undertaken without fear of trouble arising from heated bearings or other causes. A new ship may be exposed to such rough weather on her first voyage that unless her plating and riveting are carried out in a first-rate manner, she may arrive in her first port in a damaged condition. Some of us still remember during the war how new ships, built in other countries, were seriously damaged owing to the workmanship not being of a sufficiently good character. The handling of thick plates of large surfaces and the riveting of them satisfactorily to the stanchions still remains a laborious and trying piece of work for those

engaged upon it, although mechanical means exist to some extent. Glasgow has taken a leading part, providing men who in all weathers and under conditions rendered difficult by the magnitude of modern vessels maintain the high level of efficiency which is represented in the manufacture of these large hulls. The vessels of the greatest tonnage built on the Clyde have been the *Aquitania* (46,000 tons) and the *Lusitania* (32,500 tons). Other large vessels built in the British Isles have been the *Olympic* (46,439 tons) and the *Mauretania* (30,696 tons). Since the war there has been a lull in the building of liners of large tonnage and horse-power, caused, no doubt, by financial considerations, but it is gratifying to know that two large ship-owning companies are at the present time contemplating building vessels up to one thousand feet in length with a speed of over twenty knots.

Shipbuilding is especially interesting inasmuch as it combines in one structure the varied efforts of almost every class of artisan dealing with both iron and steel and cabinetmaking and woodworking generally, in addition, of course, to the large and varied amount of mechanical engineering. In marine engineering the last fifty years have, indeed, a most interesting record of progress, and in very early years such firms as Humphreys Tennant, Maudslay, Son and Field, and other firms no longer in existence, introduced a measure of precision into mechanical engineering probably not then existing in any other branch of the industry. High and low pressure triple expansion engines held their own for a considerable period, and it was, I suppose, the interesting trials of the *Turbinia* which brought about the first change from this method. It is an interesting fact that our fellow member, Sir Charles Parsons, to whom I have already alluded, should live to see such successful development of his patent, and a recent paper read by him and his coworkers describes in a very interesting manner the gradual developments and changes in design in turbines up to the present time. Such developments range from the *Turbinia*, which had a displacement of 44½ tons with 2,100 h.p., to the battle cruiser *Hood* of 41,200 tons and over 150,000 h.p.

The introduction of geared turbines, so as to arrive at relatively efficient speed as between engine revolutions and propeller revolutions, has brought about valuable economies and helped the turbine principle to maintain its reputation. The development of internal combustion engines for marine purposes has made great strides in recent years. Various types of these engines are already in active service, and a horsepower of 36,000 on four propellers has already been achieved with efficiency; probably the limit has not yet been reached. The use of oil instead of coal on board ship, especially for passenger purposes, represents many advantages, and any one who has visited the stokehold of a large passenger liner with the hundreds of men stoking with coal must realize the immense advantage, both physical and otherwise, which results from oil burning directly on the boilers. All inconvenience caused by dust in recoaling is avoided, and the boiler tending is carried out by young mechanical engineers, doing away with all the labor required by coal burning. In a vessel of large tonnage the saving in wages and maintenance of several hundreds of stokers represents an enormous economy in many directions. The question of larger horse-power or electrically driven ships is one of the problems which marine engineers are at present turning their minds to.

A new development which is now being introduced is the use of considerably higher steam pressures in boilers. The first application of this was the *King George V.*, a boat built last year on the Clyde, and our section has been

favored with a paper from Mr. Harold Yarrow dealing with some of the problems which have arisen in introducing high pressures. As you will have gathered from his paper, these problems are not solely those of the engineer who has to build the boilers. They are closely associated with steel and metallurgical questions incident to the special manufacture of parts of the boilers owing to the much greater strength required. Many of my audience, no doubt, have been interested in the valuable information we have received from the paper in question.

The defense of our country depends very largely on the efficiency of our warships, and it is impossible to speak too highly of the wonderful reliability shown by the vessels of our navy during the late war, thanks to the efficient engineering service in our navy, and the determination of the various builders in this country to produce vessels representing the highest standards of engineering efficiency. Our country, I hope, realizes how much we owe to the engineering branch of the navy for the well-proved efficiency and courage of its officers and men of all ranks in the late war. I believe that no vessel of our enormous fleet failed in action owing to breakdown of machinery, and the conditions under which the engineering staff find themselves in active warfare must be a severe strain on their courage. The response to the sudden call on the two battle cruisers, which had already been on active service for a considerable time, to make the voyage at full speed to the Falkland Islands to engage the German fleet, represented an engineering feat of a very high order.

In the mercantile marine we have great cause for thankfulness in the developments which have taken place, resulting in a very much greater comfort at sea. These efforts are naturally limited by the sizes of the harbors between which the vessels have to trade, but when we come to ocean liners the study which naval architecture has given to the production of these great vessels has resulted in our being able to visit different parts of the world with a comfort which is equal to that provided by the best hotels in any of our great cities. Shipbuilding and marine engineering have indeed taken a noble part in assisting the march of civilization and adding to our comforts in every possible way.

I wrote this part of my address on the voyage to New York on the 46,000-tons liner *Aquitania*. What a triumph of enterprise to the Cunard Company and to the naval architect and marine engineer such a vessel represents. I was watching her driving into a northwest gale from the boat deck during the day, a magnificent battle between nature's power and human skill, a sight which arouses one's admiration for the great minds who have raised engineering to so supreme a height and added so greatly to the advancement of civilization.

What does this wilderness of sea portray?
A mighty struggle, constant day by day,
'Twixt human skill and nature's changing mood
The ceaseless roar of North wind's subtle blow,
The varying power of waves that ever flow.
Such is man's battle 'gainst this angry flood.

Mechanical Engineering

It is difficult to regard mechanical engineering literally as a separate branch of engineering, for although numerically, I suppose, the mechanical engineers exceed the numbers of any other branch, nearly all their duties are associated with other types of engineering.

In connection with civil engineering all the plant occupied in harbor, dock and railway construction is in the hands of the mechanical engineer. Also in transport and marine engineering the mechanical engineer is largely engaged in the engine building of both locomotives and marine engines and other types

of auxiliary machinery for these purposes.

In electrical engineering, although this branch no doubt includes engineers without mechanical training, I would venture to say that the engineer is in an infinitely stronger position if he has received some training first as a mechanical engineer and specialized in electrical engineering afterwards.

A further important branch of the mechanical engineer's work is represented by the maintenance of machinery in the large steel works throughout the country and in the mills and factories of all descriptions. The directors of these companies are largely dependent on the advice of the engineer-in-charge in giving consideration to developments and the introduction of new types of plant to maintain production on an economic basis.

In mechanical engineering I must include the very important subject of machine-tool construction, a branch of engineering which has made very great strides and introduced many changes of design to meet new requirements in the last thirty years. Mass production on an economical basis in many industries has been the direct result of various tool-makers being able to produce special tools confined to the production of thousands of identical articles of a complicated design. I refer to articles produced at a cost of one tenth to one twentieth of what would be possible without machine tools specially designed for the purpose.

The introduction of high speed tool steel enabling far heavier cuts to be taken both by lathes and planing machines has rendered obsolete a large quantity of machine tools throughout the country, and the introduction of the electric drive has also brought about great changes in the design of machine tools. We hear to-day of some works in other countries without a single machine tool at work of prewar date, a most desirable state of things, but one which, unhappily, the economic circumstances in this country have rendered impossible up to the present time. In principle we have to admit that with our relatively high wages and general charges on industry, taxation, etc., it is not economical to continue to use machine tools which can be superseded by modern tools doing a greater volume of work in a given time, but many firms throughout the country are only able to act on this principle gradually owing to financial reasons.

We hear very strong rumors of the advent of a new type of tool steel, if it can be called steel at all, which is going to bring about a greater change in output than was represented by the introduction of high speed steel some years ago. If this becomes an accomplished fact it is good news for the toolmakers throughout the country, although it may not be equally welcomed by the many large firms already equipped at considerable capital charge with reasonably modern tools. With such keen competition, however, and the power of over-production at present existing in the country, no firm can afford to ignore the march of progress and will have to recognize the necessity for introducing machine tools of the most efficient type even at considerable financial sacrifice.

May I make a suggestion to the toolmakers in this country? When we are putting down an important new machine tool I find the makers will give every possible help in meeting our requirements in design and output, but they rarely follow up and ascertain what the real performance of the tool has been. To many of them "no news is good news." I think this is a mistake on their part. How many improvements and modifications, probably saving their clients money, could be made if they would periodically send the designer or chief draughtsman round to the works where these machines are actually at

work and ascertain at first hand from the foreman and even the workman what criticisms they have to make, and accept for careful consideration any suggestions that may be put forward based on personal knowledge of the output of the machine.

Mining Engineering

In dealing with this section I propose to confine myself to coal mining, so as to shorten what I have to say, and also to be able to apply myself more closely to the development of coal mining as affecting civilization.

Prior to the introduction of modern means of transport and the development of the iron and steel trade, the production of coal in this country, both in the aggregate and per colliery, was very small, and, consequently, the amount of virgin coal face exposed at any one time in a colliery was quite moderate. Therefore, the effusion of gas was not sufficiently large to introduce a serious danger to men working with naked lights. Ventilation was carried out by means of a furnace in the bottom of the upcast shaft, the draught being sufficient for ventilating the moderate area of the workings. Increased production necessitated the adoption of mechanical means of ventilation and large fans were installed. Science had a large share in making colliery development on a big scale possible by the introduction of the Humphry Davy and other safety lamps. These warned the miners of the presence of gas and consequent danger. The much heavier tonnage produced in a given time necessitated the introduction of large horse-power winding engines, and also of wire ropes which would be sufficiently pliable to pass over the pulleys and headgear, and also be strong enough to carry, not only their own weight which in a shaft of 500 yards is not inconsiderable, but, in addition, a loaded cage involving a weight of thirty tons or more.

A sufficient supply of coal at a moderate price is a matter of interest to every inhabitant and manufacturer in the country, and, therefore, any engineering devices which have been introduced to ensure comfort and safety of the miners and at the same time to give us our coal supply for manufacturing and domestic purposes at a moderate price, are of interest to every one. Although we unhappily know that colliery explosions occasionally occur with very dire results, and regret the many accidents to miners arising out of falls of roofs, etc., those of us who are conversant with coal mining matters realize how much science and engineering have done to lessen the risk under which the miners work. I believe that the public feel that one of the great risks is in winding the men up and down the shaft each day, and yet the careful supervision of winding arrangements, inspection of ropes and general regulations for the safety of the men are such that, so I am informed, it is only one man in forty millions who suffers an accident from this portion of the miner's duty.

The introduction of vertical ropes as guides to the cages, instead of wooden or steel guides, affords a safe and smooth running of the cages at sixty miles an hour with no more vibration than we experience in traveling in an express train at the same speed. Underground haulage has been everywhere adopted, so that the use of men for this arduous work, and, to a great extent, ponies also, has been abandoned. This underground haulage is largely carried out by compressed air engines placed underground, as in many pits it has not been felt safe to introduce electric power for the purpose except in the immediate neighborhood of the shafts. It is true that the electrical engineer has gone a long way in lessening the liability to sparking, and in enclosing the motors so as further to lessen this risk. We are still left, however, with possible danger

caused by the cables along the main roads, which however carefully placed are still liable to be damaged by unexpected falls of roof, thereby introducing a potential danger which is difficult to eliminate. At the coal face the engineer up to the present has not been able to do much to lessen the hard manual labor of the working miner, but in thin seams, say up to three feet thick, where manual work on a solid face would be almost impossible, coal-cutting machinery (in which a well-known firm in this city has successfully specialized) has been introduced, thereby lessening enormously the manual work of the miner. I venture the opinion that the introduction of machinery for this purpose has not yet reached its limit.

I regret that more members of the public do not take the opportunity of going underground and seeing the men at work at the coal face. On my various visits I always receive a warm welcome from them, and it is a real education to see what the engineer has done, and under what conditions the men work in producing an article on which we so much depend for the comfort of our daily life.

Electrical Engineering

This branch of engineering covers a very wide range of subjects and affects our social life almost more intimately than any other type of engineering, except perhaps the supply of good water and efficient drainage installations. It is impossible for me to attempt to cover the whole range of subjects embraced in electrical engineering. Telegraphy, telephony, wireless, electric lighting, electric heating, electric driving and electric power in their various ranges all enter into and affect the comfort of our domestic life. In considering this branch of engineering as a whole I find it very difficult fairly to divide the credit for its development between the pure scientist and the electrical engineer. The researches and experiments in the early part of last century on the part of Wheatstone, Faraday and Lord Kelvin, and later, coming to our own time, of Sir Oliver Lodge, Senator Marconi and other eminent scientists, have undoubtedly prepared the road to the later applications of electricity for domestic and engineering purposes, and no electrical engineer to-day can possibly efficiently carry out his duties without a greater knowledge of pure science than may be regarded as essential in other branches of engineering. It is interesting at this meeting in Glasgow to recall that it was at the British Association meeting in this city in 1876 that Graham Bell, in conjunction with Lord Kelvin, brought to the association's notice the telephone, and, further, the fact that at the Plymouth meeting of this association in 1877 I shared with many eminent members of the British Association the interesting privilege of telephoning from the saloon to the bridge on the excursion steamer, with Professor Graham Bell on board, going to and from the Eddystone Lighthouse. I allude to this fact because in those days it was regarded as a wonderful scientific invention which fascinated the most eminent scientific men. Yet to-day we take it all for granted, and hardly realize the comfort and convenience that the introduction of the telephone has brought into our lives.

I admit that the introduction of wireless telephony and telegraphy has amazed the world to a greater extent than that of the telephone, and it is certainly more within the capacity of the pure scientist than of the engineer to explain the scientific problems involved. I am not going to state whether the introduction of wireless broadcasting into our homes is an amenity or not, *chacun à son goût*, but when we turn to the application of wireless telegraphy we accept without hesitation the benefits it has brought into the world. It is im-

possible to say what number of lives have already been saved by boats in distress having been able to secure help from other vessels by means of wireless communication.

The development of electricity as a mechanical driving power was very slow up to a certain date. For instance, I went by electric train from Berlin to Charlottenburg in the spring of 1882. The running of the railway appeared to be quite satisfactory, and yet it was at least ten, and I think fifteen, years before any real development took place in the way of electric railways or trams, the difficulty, I believe, being in producing satisfactory dynamos on an economic basis. The first electric railways in this country, so far as I know, were the Liverpool Overhead Railway in February, 1893, and the Liverpool to Southport Railway in April, 1904. The practicability of electric driving on main lines is still a matter under discussion. The only country which has whole-heartedly adopted this system is Switzerland, a country which has undoubtedly been influenced by the uncertainty of obtaining a uniform supply of coal at reasonable prices, coupled with the fact of an efficient and ample supply of water-power for their generating stations. The Barberine reservoir, which has now been completed, and the large reservoir at the Grimsel Hospice now under construction are fine examples of civil engineering work carried out for the purpose of developing electric current for the Swiss railways.

In this country considerable developments are taking place on the various main lines, but engineers are at present concentrating on the use of electric driving mainly for suburban traffic, and not at present on main line long-distance expresses. It is probable that the great extension of high-power installations throughout the country contemplated by the electricity commissioners will render possible a more extensive use of electric trains on our main lines.

The application of electricity for driving purposes in the various large works in this country made very rapid strides as soon as electrical machinery for the purpose was available. I remember showing to a former president of this association, Sir William White, the first set of Belliss and Morcom engines we had installed in a works in the Midlands, the various machines in these works at that time being driven by steam engines in different shops and line shafting. Sir William said to me then, "Do you realize that within ten years every machine in these works will be electrically driven?" I think few engineers realized at that time that electric driving would replace so rapidly the existing methods. Apart from the economy represented by its introduction the change enabled the management to register the amount of power used by each type of machine under varying loads of service, a circumstance which was impossible with belt-driven machines, when the power varied according to the tightness and width of the belt. The greater efficiency, however, is really represented by the fact that in a large works electricity can be produced in bulk at a central power station at a low rate of cost, and the loss in distributing to the various departments through high-tension cables and transformers to lower voltage in the different sections of the works is insignificant compared with the saving represented by a consumption of coal and a cost of maintenance far below what is possible with direct steam driving. Electricity has in some measure been introduced into mining engineering, as I have mentioned in the mining section; electric winding engines have been adopted with satisfactory results; but as the fuel supply for steam raising at the various collieries, especially where coke ovens are installed, is much less costly

for providing power than in a works without such auxiliary facilities, the economy in the use of electric winding *versus* steam is naturally not so great.

The public, I think, fails to realize that electric lighting for domestic purposes, if charged at a reasonable rate, does not represent any real charge on the household. It is so clean in its application that, in my opinion, the necessity for cleaning and decorating which is avoided in many cases represents a greater saving than the amount paid for electric light. In addition we have the great advantage that it does not burn oxygen, and therefore we have more healthy conditions in our rooms compared with any other method of lighting. I feel sure that those who have introduced electricity into their houses for the purpose of cooking and hot-water supply will never go back to the old system of kitchen fire for this purpose, owing to the former's efficiency and cleanliness in application. It appears to me that all that is wanted for a much larger use of electricity domestically is a reduced charge by the various supplying companies and corporations at least to the level which exists in many of our cities already. It is hoped that the work of the electrical commissioners in installing bigger units of power throughout the country may bring down the cost so as to place electricity within the reach of every householder.

Since I roughed out this address it has been my privilege to make a journey across America from New York to the Pacific Coast, and return through the Rocky Mountains and Canada, and throughout my journey I could not help realizing how large a share engineering in its broadest sense has taken in developing these wide regions. First comes the railway as a through communication between east and west for three thousand miles. Gradually settlers come and farming and lumber work commences, their progress only being possible with the aid of railway transport. Gradually small towns spring up, requiring the assistance of engineers for water and drainage. In the torrid provinces of New Mexico and Arizona the water question is a very serious one, and large irrigation schemes will have to be introduced. At Grand Canyon, for instance, the water for household and farm use is brought nearly two hundred miles by train in large special wagons. Then mineral wealth is discovered, and the mining engineer appears and requires his varied plant to be brought by railway from the manufacturing centers. In the mountainous parts of the country large hydroelectric plants are being developed, thus calling on the electrical engineer for his services, and I might quote many other illustrations of a similar nature.

Yes, ladies and gentlemen, those of us who are spending our lives in engineering work may justly be proud of the large share the members of our profession are taking in promoting and advancing the civilization of the world, and thereby bringing happiness and prosperity to many thousands of our fellow countrymen.

I realize that within the limits of this address I have only been able to touch to a very limited extent on the association of the different branches of engineering as affecting our civilization. I hope, however, I have said enough to interest my audience in a side of engineering that is not often brought out, and that those of us who are actively engaged in engineering may earn the respect and confidence of our fellow citizens.

EDUCATIONAL TROBRIANDERS AND THE PROFESSORIAL ILLUSION

By Professor JOHN M. FLETCHER

TULANE UNIVERSITY, NEW ORLEANS, LA.

MALINOWSKI, the Polish anthropologist, tells us that the Trobrianders, who inhabit a coral archipelago of the South Sea Islands, have never been able in their thinking to connect the birth of a child with the antecedent procreative act. Children, according to the belief of these people, come from Tuma, the Island of the Dead, a land populated by the souls of persons who have died on earth. On arriving in this land the souls acquire the power, once possessed by them but lost, of renewing their youth. After a round of rejuvenations the souls may, with the guidance of Baloma, the presiding deity of the Island, return to their original earthly abode by entering the bodies of women of their original clan or sub-clan.

If we are disposed to follow the Socratic analogy of thinking of the business of instructing the youth as a sort of midwifery of ideas, we may find ourselves to be closer akin to the Trobrianders than we may imagine. Indeed we are, it seems, in quite as primitive a stage in respect to the growth of minds as are the Trobrianders in their idea concerning the growth of bodies. That we know little concerning causes and effects in education is a conclusion which we are about to be shocked into confessing. Some of our shockers are even going so far as to insinuate that we have not reached the stage of being intelligently concerned about the matter. President Faunce, of Brown University, has recently been quoted as saying, for instance, that "nowhere else is education so pointless and aimless, so blind in its objectives, so indifferent to any specific outcome, as in America." In the light of this significant confession it is surely in order to ask what it is that gives such authority and solemnity to the requirements set up by curriculum committees.

Are we sufficiently familiar with mental embryology to be trusted with the authority in these matters which such committees consider to be their inherent right? In order to make clear the issue involved in this query let us, after the fashion of lawyers, put the hypothetical question: Suppose that before a representative committee on graduation requirements we were to lay the candidacy of a certain young man. Suppose that the young man in question knew no Latin, no English, no modern language, no Roman and little Greek history, very little mathematics and physics, no algebra, no calculus, very little about human anatomy and physiology, very little about astronomy, practically nothing about chemistry, geology, biology or botany, and his entire library could be carried in a wheelbarrow. To award an academic degree in spite of a confession of such ignorance as this would turn our educational system topsy-turvy. Yet, let me confess, this is not a hypothetical but a concrete case. Plato, according to L. P. Jacks,[1] would, if living to-day, be compelled to make just such a confession. Was Plato an educated man? Can we with all of our latitude in curriculum making grow such a mind as his?

The upshot of the situation seems to be that we are in a pre-scientific age respecting education and we are attempt-

[1] *Atlantic Monthly*, Febr., 1924.

ing to function as if we were in a scientific age. Scientific method, wherever applied, presupposes the understanding of cause and effect and a certain degree of control in the manipulation of causal factors. Pre-scientific empiricism proceeds by the method of trial and error, and has no criterion of the correctness of its methods except the goodness of the end results. I can not accept the criticism of modern education that would have us believe that menticulture was once understood but has become a lost art. Those who have such faith in ancient ways may be interested to read an old Latin saying quoted by Paulsen in his book on German universities, a saying which has a distinctly modern flavor though it dates as far back as the Middle Ages: *Sumimus pecuniam et mittimus asinum in patriam.* Probably the chief difference between ancient and modern methods of turning out this sort of educational product is that we have made some progress in quantity production.

The urge toward scientific control in education has undoubtedly been present. We seem, however, to be grossly in error as to the extent to which we have succeeded in effecting this control. We have been searching for a sort of synthetic formula of education. In the more scientific methods of recent years we have turned away from the consideration of the relative values of various cultural products of civilization, and have centered attention upon the learning personality and its learning processes. Pursuant to this aim we have formed and are still forming theories as to the essential components of the human mind. But when, in acting on such theories we attempt to fashion a mind as we have, by following a similar method, learned to produce synthetic camphor or rubber, our efforts are, according to many observers, not always successful. In our faith in the analytic methods of science we have broken the human mind into many sorts of fragments, now of sensations and their residues *à la* John Locke, now of primitive instincts *à la* G. Stanley Hall, now of muscle twitching *à la* John B. Watson, but as in the case of the tragedy of Humpty Dumpty, we have not been able to get these fragments together again into a going concern. Yale, according to press reports, acting on the assumption that its present seniors are educated, seems to be endeavoring to find out from them through questionnaires how it happened. These seniors are called upon to give testimonials as to what they consider to have been the most beneficial studies pursued by them in their college careers; a case of educational empiricism, of judging the method by the character of the end products. Society in general seems to be able to recognize an educated man when one comes along, but how to produce them we are still endeavoring to learn. The factors that enter into the making of an educated mind are so multifarious and they operate over such a wide span of time that it is difficult to make connection in our minds between causes and effects. Hence even primitive empiricism is difficult to apply. What we call the stupidity of the Trobrianders about the birth of children is different from our own helpless ignorance as to cause and effect in education only in degree.

In the present state of failure of our attempts at developing scientific educational formulae one may find good ground to advocate a frank adoption of out-and-out empiricism as the best present guiding principle. Successful empiricism is better than an unsuccessful scientific formula. What we have at present is a mixture of the two, and hence neither can succeed, and hence, further, neither can be disentangled from the other in tracing the responsibility for success or failure, as the case may be.

The chief difficulty in the way of adopting an empirical basis of estimating the value of educational methods and materials is that educated Yale University seniors and educated college professors alike when called upon to tell how they got that way are subject to what may be designated "the professorial illusion," so named because college professors seem so subject to it that they almost deserve the distinction. The professorial illusion, like any other sort of illusion, is a parallax or distortion of judgment caused by an egocentrism of viewpoint. Man originally conceived a geocentric universe because he has an egocentric mind. The hub of the universe sticks out in our own villages because the locus of all hubs is the individual mind. If one makes his bed in hell this same hub will be there. Provincialism is a mental, not a geographical, phenomenon. We all, says Bacon, have a cave or a den of our own, "which refracts and discolors the light of nature."

To apply: All men, whether learned or unlearned, have their educational philosophies. With both the learned and the unlearned these philosophies represent the formulation of personal experiences into principles of universal applicability. If one doubts the existence of such philosophies he needs but to do a bit of psychoanalytic work on his own accord. Let him choose his professorial victim and provide the simple paraphernalia of a pipe, an easy chair and the softened light of the study lamp. The technique to be employed is simple. The first and sometimes the only step in the procedure is to introduce the question as to how the victim came to be what he is. Once the stream of reminiscing and philosophizing has begun to flow only good listening is required. The listener will soon be rewarded by detailed accounts of how circumstances, whether good or bad, wealth or poverty, social contacts, early parental discipline, whether severe or *laissez faire*, everything, in short, of whatever kind, have contributed to make out of the subject of the test the man that he is.

Now, let me pause here to say in parenthesis that this universally human reaction is a beneficent one, and undoubtedly has its biological uses. In the days when men were not afraid of being called vitalists they used the phrase *vis medicatrix naturae* to describe the disposition of a living organism to take care of itself. Molière, for instance, said that physicians amused the patient while God did the healing. It is not scientifically fashionable nowadays to speak of the "healing power of nature," but we may describe the same phenomenon as the capacity to manufacture anti-bodies to combat disease, when we are talking about physical ills, and when we are talking about mental ills we must adopt the modern lingo about rationalization, defense reaction, etc. At any rate we have here a case where Nature, contrary to what Tennyson said about her, is found to be not at all "careless about the individual life." The mind, in short, like the body seems to resist disease, disorder, annihilation. Injurious memories, thoughts about failures and the emotions connected with such thoughts, either become covered by the veil of amnesia, or else, in the pipe-smoke of retrospection, have a new light thrown upon them, so that we may live with them mentally without injury or pain. It is by virtue of this beneficent power that healthy minds of all ages have achieved the triumph of seeing sweetness in the "uses of adversity," and of welcoming life's rebuffs.

Like all other beneficences of nature, however, this reaction tendency has its errancies, of which the professorial illusion is one. It is not true that the history of the world is the best criterion of what should have been. The world as well as human lives may be assumed to

have been better off if some things had never happened. Most people will accept this conclusion when applied to the history of the world, but when thinking of their own personal history agree with Samuel Butler's character, Pontifex, who said: "As I look back upon it, I respect myself more for having never once got the best mark for an exercise than I should do if I had got it every time it could be got. I am glad Skinner (the headmaster) could never get any moral influence over me; I am glad I was idle at school, and I am glad my father overtaxed me as a boy—otherwise, likely enough, I should have acquiesced in the swindle, and might have written as good a copy of Alcaics about the dogs of the monks of St. Bernard as my neighbors."

Once an observer gets interested in collecting specimens of this fascinating mental phenomenon they will begin to bob up in the most unexpected quarters. Example: A certain educational authority of the Mid-West was heard talking to a group of college students in a Sunday school class. Being in a mood to moralize, he fell to telling them about why he turned out so well—of course no one ever puts it so bluntly as that. The thing for which he felt the greatest gratitude was the fact that his parents in the early years of his life sent him to a school where only two things were taught, namely, music and manners. One of his graduate students, on hearing this, remarked: "I do not know how much *music* he knows."

The pedagogical damage wrought by this personal parallax of judgment results not only from the fact that we may be mistaken as to what may have been the best thing for ourselves, but more especially from our insistence, if we have the authority so to do, that others shall be required to do what we have done. We may possibly be correct as to what particular studies have contributed to our intellectual development, and still have no right to conclude that these same intellectual pursuits will contribute a same amount of benefit to all others who may follow them. We are, in short, in a pre-scientific stage of knowledge concerning curriculum formulation, although when we have presented to us, say, for education, a human mind, presumably empty, we assume that by putting in a little of this subject and a little of that we shall produce an educated mind. The various stuffs in our educational dispensaries are, by common tradition at least, labeled according to the effects they are expected to produce. It is, surely, fair to presume that if we expect these various subjects to produce predictable effects of a certain kind in the students who study them, the teachers, who may be presumed to have mastered such subjects, ought to exemplify such effects in maximum degree. If they do not, then we must be mistaken as to what such subjects will do for students.

There is an old story that was current during the suffragist movement in England that a monocled son of nobility gravely delivered to an ardent suffragette one day the opinion that women should not vote because it tended to make them too masculine. The suffragette replied that voting had apparently not had that effect upon him. When our bespectacled pedagogical gentry, under the spell of professorial illusions, to which we are all subject, are gravely delivering opinions and making laws in curriculum committees, it might be a wholesome thing for our suffragette, like Portia, to come into court and take the part of defenseless youth. Few of us who teach have the courage to meet such situations in so prompt and so effective a way as she met hers.

Viscount Bryce some years ago dichotomized the subject-matter of education into "external objects, animate and inanimate," on the one hand, and "the

products of thought," on the other. The one he called the domain of science, the other that of the humanities. The former is qualified, he thought, to give knowledge and practical efficiency; the latter to give culture. To his mind one may as well expect to gather grapes of thorns or figs of thistles as to expect culture to result from the study of "tissues," "electrons," "sodium chloride" and "cephalopoda." In spite of the fact that it is to these despised natural phenomena themselves rather than to books written about them that the liberalizing minds of all ages have turned for their inspiration, Bryce would have us believe that educational products are determined by the character of the subject-matter, that the study of recorded thoughts will give us one result, and the study of things will *per se* give us something quite different.

The ancient and honorable discipline of mathematics has always arrogated to itself the peculiar quality of developing the minds of its devotees. But for this assumption nine tenths of the mathematics now in our curricula would be eliminated. When a teacher of that subject takes this position either explicitly or implicitly, there should be present someone as wise and as courageous as the suffragette previously mentioned to say, "What a whale of a mind you must have!" Now, indisputably, many mathematicians have good minds. There is, surely, nothing to hinder the happening of such a thing. But some mathematicians are so impressively dull when they stray from the confines of their specific field of interest that one hesitates to generalize. The striking disagreement between the theoretically assumed and the actually achieved effects of the study of this, that and the other subject seems, however, so far as pedagogical thinking goes, never to disturb the deliberation that goes on in our curriculum dispensaries. The truth of the matter is that we have no means of evaluating the *effects* of our instruction. We measure and grade the *stuff*, the *content* which has managed to survive in the minds of our students at the time of our periodic probings. The *effects* are taken for granted.

Hope "springs eternal" that the youth of to-morrow will see things a bit more clearly than we of to-day are seeing them. That they are having glimmerings of insight may be inferred from the following personal experience. A laboratory chum in a moment of frank confession remarked: "If I thought that I should ever turn out to be like Professor Blank I should now go out and soak my head in gasoline." Why he preferred that particular method of procedure he did not stop to explain. He was taking Professor Blank's subject, and no doubt Professor Blank, after the usual fashion, was quite convinced of the wholesome effects to be expected from the study of his subject. But if our curriculum formula of education were valid, if the study of the various subjects taught by the various Professors Blank, and if the requirements for graduation were as rigid as in former years, the price of gasoline would probably go up in the neighborhood of some of our colleges, provided this were the only means of exit under academic provocations.

Many educators are now being heard to say that probably fifty per cent. of the students in many colleges are failing to take advantage of their opportunities, and would be better off elsewhere. We seem to accept this high death-rate with about the same fatalism as that with which we once accepted plagues and pestilences. Among the casualties in education as in war must be included, of course, not merely those who are killed, but also those who are wounded, gassed or otherwise disabled for the battle of life. There are many who complete their

education according to the stipulated conditions and hence are not to be numbered among the dead, but who, while they have "picked up wit as pigeons peas" and have dealt it out again as the instructor "doth please," have not risen above the mass either in intellectual tastes or social consciousness. From among the latter type come all too many candidates for the high and honorable calling of college teaching.

The remedy for our present educational miscarriage (thinking again of the Trobrianders, our comrades in ignorance) does not, in spite of claims to the contrary, consist of a return to the curriculum systems of the past, nor will it be found in the reorganization and perfection of the curricula of the present. It is, in short, not a matter of curriculum. While it seems indisputable that education is accomplished only through impacts between personalities, it is idle to fancy that we may retrieve ourselves by attempting to restore by force of arms the "passing" college professor to his quondam position of authority and influence. The ancient curriculum and the bygone professor, we must remember, functioned in an ancient setting. Between the curriculum, the professor and the setting, the setting is the all-important thing. If the professor with his personality is gone; if in the colleges as in society in general "the individual withers and the world is more and more," it still remains true that institutions may have personalities. Guided only by our empirical thinking we have noted for ages the educational effectiveness of institutions that possess what we call "atmosphere." But how to go about producing this indispensable agency is not a subject on which our curriculum committees spend any of their time. They are occupied with hours of credit, units for graduation; in short, about ingredients, formulae, prescriptions. Most of our administrators, captivated as they are by American ideals of bigness, are leading us toward depersonalization, disintegration, elephantiasis. To have atmosphere, to be able to educate effectively, our institutions must be unified, integrated, be-souled. How this can be done is another story.

HEREDITY CONCEPTS OF THE ANCIENT HINDUS

By Dr. FREDERICK S. HAMMETT

THE RESEARCH INSTITUTE OF THE LANKENAU HOSPITAL, PHILADELPHIA

FOR some years past I have been extricating from the Müller literal translations of "The Sacred Books of the East" the statements concerned with biological matters. This was done with the intention of at some time collecting them together into a book as a contribution to the historical development of our present state of biological knowledge. Due to the press of activities in other directions, however, this bibliophilic diversion seems in a fair way to end otherwise than by first intention. Certain references in Raymond Pearl's recent pamphlet on "The Present Status of Eugenics" relative to man's early concepts of heredity stimulated memories of explicit statements of the ancient Hindu writers. Therefore, there was nothing to do but to cull them out and set them forth for the pleasure of those who admire the past.

A word as to the source of the material. The quotations are direct transcriptions from the literal translation of classical ancient Hindu manuscripts made by competent scholars and edited by Müller. Correspondence with American scholars has established the fact that the series is the standard for students in this field, and that the authenticity is unquestioned. Although the exact age of the writing of the originals is unknown, it is known that they had their beginnings several centuries antecedent to the Christian era, that the earlier ones were developed prior to the rise of Grecian civilization and the later ones independently thereof.

Though I would spare the reader as much mental effort as possible, the nature of the material makes impossible its presentation in flowing, easy style. A certain apparent disjointedness is inescapable. These ancient scientists were, pleasingly or not, according to the point of view, addicted to putting down their conclusions in sharp, concise phrases. The absolute necessity for this is evident. Ink and paper were not plentiful, reproduction was tedious and time-consuming, and editors were presumably unlenient, not apparently so as they are now. The exigencies demanded condensation, and this was accomplished with marvelous clarity. As a result each phrase, the crystallized conclusion from thoughtful observation, becomes a nucleus of intellectual appreciation for the biological connoisseur and a shining example for the recorder of scientific work of to-day.

Let us now turn to the records themselves. The principle of straight-line descent was not only recognized by the ancient Hindu scientists, but was stressed in some completeness. See what they taught.

"The same seed which is laid is brought forth."[1] "The seed infused into the womb is fashioned. . . For whatlike the seed is fashioned in the womb, suchlike it is born."[2] "The animal becomes manifest to its own form, cow to cow, horse to horse, and man to man."[3] "On comparing the seed and the receptacle (of the seed), the seed is declared to be more important, for the offspring of all created beings is marked by the characteristics

[1] "Satapatha Brahmana," vol. 41, 6, 1, 3, 20; volume numbers in all references refer to Müller's series of "The Sacred Books of the East," Oxford Press.

[2] *Ibid.*, 6, 7, 2, 5: 7.

[3] *Ibid.*, 6, 3, 1, 22.

of the seed. Whatever (kind of) seed is sown in a field, prepared in due season, (a plant of) that same kind, marked with the peculiar qualities of the seed springs up in it. This earth, indeed, is called the primeval womb of created beings; but the seed develops not in its development any properties of the womb. In this world seeds of different kinds, sown at the proper time in the land, even in one field, come forth (each) according to its kind.—That one (plant) should be sown and another be produced cannot happen; whatever seed is sown (a plant of) that kind comes forth."[4] "They yield their products, each according to its own faculty, reach, and particular nature of the germ . . ."[5] "It is from the remote end downwards that a race is propagated."[6] "Wherefore one is born, suchlike he becomes."[7]

These biological facts undoubtedly participated in the development of the idea of immortality through germplasm continuity. This principle, commonly attributed to Weismann, or as a logical conclusion to be drawn therefrom, had its inception ages before this biologist appeared upon the stage. The name of its originator is unknown. It is none the less significant that the idea was current in the earliest stages of natural science development. Read what was taught:

"Seed is . . . infused into the descendants, and by that infused seed descendants are generated again and again."[8] "The seed which is infused into the womb becomes generative."[9] "Now it can also be perceived by the senses that the (father) has been reproduced separately (in the son); for the likeness . . . is even visible, only (their) bodies are different."[10] "In thy offspring thou art born again, that, mortal, is thy immortality."[11] "Undecaying and immortal is this (earth), and undecaying and immortal is the vital energy (sperm)."[12] "The generative power is immortal."[13]

[4] "The Laws of Manu," vol. 25, 9, 35–40.
[5] "Saddharma Pundarika," vol. 21, 5, 15.
[6] "Satapatha Brahmana," vol. 12, 1, 4, 2, 4.
[7] *Ibid.*, vol. 41, 7, 4, 1, 1.
[8] *Ibid.*, vol. 12, 1, 5, 3, 16.
[9] *Ibid.*, vol. 41, 7, 3, 1, 28.
[10] "Apastamba (Sacred Laws)," vol. 2, 2, 9, 24, 2.
[11] *Ibid.*, vol. 2, 9, 24, 1.
[12] "Satapatha Brahmana," vol. 26, 2, 3, 1.
[13] *Ibid.*, vol. 41, 7, 3, 1, 46.

It is not impossible that early recognition of the principle stated above lies at the root of the development of the caste system of India. It is written that "a base born man either resembles in character his father, or his mother, or both; he can never conceal his real nature."[14] The natural reaction to such observation in the field of heredity would be the segregation of the base-born into classes with which the non-base-born should not intermingle for fear the base traits might be passed on and thus contaminate the descendents.

The idea that certain diseases are inherited is mentioned in more places than one and specifically intimated in the statement that a man might be ill "in consequence of a sin committed by (thy) father or by (thy) mother."[15] These theoretical concepts derived from close observation were put to practical use in the directions given for choosing a mate. Thus the admonishment:

. . . in connecting himself with a wife, let him carefully avoid the ten following families, be they ever so rich in kine, horses, sheep, grain or (other property): (Viz.) one which neglects the sacred rites, one in which no male children (are born), one in which the Veda is not studied, one (the members of) which have thick hair on the body, those which are subject to hemorrhoids, phthisis, weakness of digestion, epilepsy, or white and black leprosy. Let him not marry a maiden (with) reddish (hair), nor one who has a redundant member, nor one who is sickly, nor one with either no hair (on the body) or too much, nor one who is garrulous or has red (eyes). Let him wed a female free from bodily defects—a moderate (quantity of) hair on the body and on the head, small teeth and soft limbs.[16]

In another place similar directions are given with the additional command which indicates a knowledge of the possible harm to be derived from inbreeding. It is written:

Nor (should he marry) one descended from his maternal ancestors within the fifth, or from

[14] "The Laws of Manu," vol. 25, 10, 59.
[15] "Hymns of the Arthava Veda," vol. 42, 2, 5, 30, 4.
[16] "The Laws of Manu," vol. 25, 3, 6–10.

his paternal ancestors within the seventh degree. . . Nor one diseased. Nor one with a limb too much. Nor one with a limb too little. Nor one whose hair is decidedly red.[17]

It would be interesting to know the basis of the antipathy to persons of red hair. Perhaps it lay in a belief which exists even to-day that such were commonly termagants and hence unsuited to be wives of males demanding complete submission, a characteristic not entirely Hindu in its nature.

In a race in which the idea of male dominance was and still is so prominent, it is not surprising that sex determination was a matter of great interest. The not too oldish modern idea of some biologists that a male child is the result of a male germ was anticipated some thousands of years ago. Even our chromosomologists must admit that the statement—"Into thy womb shall enter a male germ, as an arrow into a quiver! May a man be born there, a son, ten months old!"[18] is not unprophetic.

Specific ceremonies were necessary for the begetting of a child of either sex. To the psychologist the symbolism in these is at once apparent. The ceremony for the male "must be performed before the embryo begins to move."[19] To get a male child the husband must give to the wife during the third month of her pregnancy, "after she has fasted, in curds from a cow which has a calf of the same color (with herself), two beans and one barley grain for each handful of curds. To his question 'What dost thou drink? What dost thou drink?' she should thrice reply, 'Generation of a male child! Generation of a male child!' Thus three handfuls (of curds). He then inserts into her right nostril, in the shadow of a round apartment, (the sap of) an herb which is not faded."[20] Other details leading to the same end are devised. The husband "should seize her thumb if he desires that only male children may be born to him. Her other fingers (if he is) desirous of female (children)." He should seize "the hand on the hair side together with the thumb, (if) desirous of both (male and female children)."[21] "He shall seize the hand of a girl. Who should possess (the auspicious) characteristics required. Whose limbs shall be proportionate. Whose hair should be smooth. Who should also have at her neck two curls turned to the right. (Of such a girl) he shall know that she will give birth to six men."[22]

Over and above these symbolistic appurtenances of sex determination the ancient Hindus advocated dietary regulations to bring about the desired end, much as do certain food faddists of today. See if these thirty-century-old rules should be any less efficacious than those promulgated in these times of ultra-civilization.

If a man wishes that a white son should be born to him . . . then, after having prepared boiled rice with milk and butter, they should both (man and wife) eat, being fit to have offspring. And if a man wishes that a reddish son with tawney eyes should be born to him . . . then, after having prepared boiled rice with coagulated milk and butter, they should both eat, being fit to have offspring. And if a man wishes that a dark son should be born to him with red eyes . . . then, after having prepared boiled rice with water and butter, they should both eat, being fit to have offspring. And if a man wishes that a learned daughter should be born to him . . . then, after having prepared boiled rice with sesamum and butter, they should both eat, being fit to have offspring. And if a man wishes that a learned son should be born to him . . . then, after having prepared boiled rice with meat and butter, they should both eat, being fit to have offspring.[23]

[17] "The Institutes of Vishnu," vol. 7, 24, 10–15.

[18] "Hymns of the Arthava Veda," vol. 42, 4, 3, 23, 2.

[19] "Sankayana Grihya Sutra," vol. 29, 1, 20: "The Institutes of Vishnu," vol. 7, 26, 2.

[20] "Asvakayana Grihya Sutra," vol. 29, 1, 13, 2–5.

[21] *Ibid.*, 1, 7, 3–5.

[22] "Sankayana Grihya Sutra," vol. 29, 1, 5, 5–10.

[23] "Brihadaranya Upanishad," vol. 15, 6, 4, 14–18.

It is hardly necessary to expatiate on these data. They are self-explanatory, and any attempt to adorn them would be presumptuous. I can not resist suggesting, however, that in view of this evidence of early biological wisdom we should look carefully to our laurels in order to be sure that they are not indurated with the dust of the ages.

THE PREHISTORY OF TELEVISION

By Dr. BERTHOLD LAUFER

CURATOR OF ANTHROPOLOGY, FIELD MUSEUM OF NATURAL HISTORY, CHICAGO

In his drama "Back to Methuselah" George Bernard Shaw depicts the following scene as a reality in the year 2170: the head of the British government is holding a conference with his cabinet ministers, who are several hundred miles distant, in this manner—that he operates a switchboard near his desk and, by pressing a certain key, makes appear on a silver screen a life-size picture of the person to whom he desires to talk and whose voice is simultaneously transmitted.

In April, 1927, the Bell Telephone Laboratories gave the first practical demonstration of transmitting over electric wires the pictures and voices of moving persons, voice and image being perfectly synchronized. A two-way telephonic communication was maintained between Washington and New York. Secretary Hoover in Washington opened the demonstration, and the illuminated image of himself cast over the wire on a screen in New York synchronized perfectly with his voice that was heard over the telephone at the same time. One telephone line was used for transmitting the voice, another for transmitting the television current and a third for synchronizing the electric driving-motors at each end of the lines. It has since been demonstrated that both the voice and the "picture" currents can be sent over the same wire or, in the case of radio transmission, over the same wave-length.

While television at present is a fact, it has been the dream of mankind for hundreds and thousands of years. In my monograph, "The Prehistory of Aviation," recently published by Field Museum, Chicago, I have emphasized the fact that human imagination has been of paramount importance and proved most fertile in the development of mechanics and inventions and that the trend of man's mind toward the romantic and adventurous has resulted in the conquest of the air. The essential point is that many fundamental contrivances have not been reasoned out logically through progressive scientific thought, but that man's mind conceived them through visionary reveries as an accomplished fact and then proceeded to work toward this imaginary goal. Thus television also has its prehistory in the domain of oriental folk-lore, a brief outline of which is given on the following pages.

In Firdausi's great epic poem, the Shāhnāmeh ("Book of Kings"), figures a cup which mirrors the world and distant persons. It is the property of King Kai Khosrau and appears in the love-story of Bizhan and Manizha. The king, while holding a feast, receives a petition for succor from the people of Irmān, whose country is being ravaged by wild boars, and sends Bizhan and Gurgin to scour the country of them. Through the machinations of Gurgin, who envies him, Bizhan falls in love with Afrasiyab's

daughter, Manizha, who carries Bizhan off to Turan and hides him in her palace. He is discovered and imprisoned in a pit with Manizha as his attendant. In the meantime Gurgin has returned to Iran, where his lame story rouses suspicion. By means of the divining-cup Kai Khosrau ascertains Bizhan's situation and dispatches the hero Rustam to deliver him. The king says to Giv, Bizhan's afflicted father (in Warner's translation):

Then will I
Call for the cup that mirroreth the world,
And stand before God's presence. In that cup
I shall behold the seven climes of earth,
Both field and fell and all the provinces,
Will offer reverence to mine ancestors,
My chosen, gracious lords, and thou shalt know
Where thy son is. The cup will show me all.

Then the poet narrates how Kai Khosrau saw Bizhan in the cup that shows the world:

When jocund New Year's Day arrived, Giv yearned
For consultation with that glorious cup,
And came, bent double on his son's account
But hopeful, to Khosrau who, seeing him
With shrunken cheeks and sorely stricken heart,
Went and arrayed himself in Ruman garb
To seek God's presence. Then before the Maker
He cried and oft-times blessed the Shining One,
Imploring of the Succorer succor, strength,
And justice on pernicious Ahriman,
And then returning to his throne, assumed
The Kaian crown, took up the cup, and gazed.
He saw the seven climes reflected there,
And every act and presage of high heaven,
Their fashion, cast, and scope, made manifest.
From Aries to Pisces he beheld
All mirrored in it—Saturn, Jupiter,
Mars, Leo, Sol and Luna, Mercury,
And Venus. In that cup the wizard-king
Was wont to see futurity. He scanned
The seven climes for traces of Bizhan,
And, when he reached the Kargasars, beheld him
By God's decree fast fettered in the pit,
And praying in his misery for death,
With one, the daughter of a royal race,
Attending him. The Shah, with smiles that lighted
The daïs, turned his face to Giv and said,—
"Bizhan is yet alive; be of good cheer!"

In one of the stories of the Arabian Nights (No. 271) the three sons of a Sultan of India—Prince Husain, Prince Ali and Prince Ahmed—undertake a year's journey into a distant part of the world to find some unusual treasure for their royal father, who had promised the hand of a princess to him who would bring back the rarest jewel. Prince Ali traveled to Shiras, capital of Iran, and while rambling in the bazar of the city, one day met a man who carried in his hand an ivory tube about a yard long and offered it for sale at the price of thirty thousand sequins. The prince thought him to be a fool, as he demanded so enormous a sum for such a wretched thing, but was soon informed that this broker was wiser and more sensible than all others of his profession. He examined the ivory telescope, which was equipped with a piece of glass at either end and which if placed in front of the eye brought anything close to it, even though it may have been many hundreds of miles away. Moreover, this tube had the miraculous power of showing any object or any person its owner desired to see. Prince Ali wished to see his father whom he had left in India, and no sooner did he hold the ivory tube close to his eye than he espied him hale and hearty seated on his throne and giving judgment to the people of his land. Then he demanded to behold his beloved princess, and immediately he caught sight of her as she was leisurely reclining on a couch, chatting and laughing and attended by a flock of maids.

In Grimm's tale, "The Four Skilful Brothers," the situation is very similar to that of the preceding story. Four brothers go out into the world to earn their living and to learn a craft. One becomes an expert thief. The second meets a man who asks him what he wishes to learn in the world. "I do not know it yet," he replies. "Come along with me and become a star-gazer; there

is nothing better than that, nothing will be hidden to one." He consented and became so clever a star-gazer that his master, when the boy had finished his apprenticeship and would leave him, presented him with a telescope and said, "This will enable you to see what occurs on earth and in heaven, and nothing will remain concealed to you." He meets with his three brothers, who have also acquired an extraordinary art, and soon there is an opportunity for them to put their knowledge to the test. The king's daughter was kidnapped by a dragon, and the king made it known that he who would bring her back should receive her as his consort. The four brothers decide to deliver her from the dragon. "I shall soon know where she is," said the star-gazer, looked through his telescope and announced, "I behold her, she is seated far away on a rock in the sea and beside her the dragon who guards her." Then he went to see the king and requested a ship for himself and his brothers, and crossed with them the sea till they arrived at the rock. They return with the king's daughter, and naturally engaged in a quarrel as to which should have her as his wife. The star-gazer said, "If I had not espied her, all your arts would have been futile; therefore she is mine." As all their claims were of equal merits, the king decided that no one should get her, but assigned to each a half kingdom as his reward.

Lucian, in his "True History" (I, 26), relates that in the palace of Endymion, king of the moon, he saw a large mirror placed above a well of mediocre depth. In descending into this well, it was possible to hear whatever was talked on earth; and in lifting one's eyes toward the mirror, one saw all towns and all nations as though one were in their midst. "I saw there my parents and my country," he adds, "I do not know whether they saw me too. I do not venture to affirm it, but he who declines to believe me might go to the moon, and will then convince himself that I am not an impostor."

Zosimus, an alchemist who lived in Egypt during the third and fourth centuries A.D., discusses the electron, an alloy of gold and silver, and mentions a magic mirror which Alexander the Great had made of it and which subsequently was exhibited in the Temple of the Seven Gates (corresponding to the seven heavens) above all spheres. In this mirror one beheld one's own future and destiny until one's death. This was a divine mirror symbolizing God (compare Epistle of James, I, 23–24; I Corinthians XIII, 12; II Corinthians III, 18).

In 331 B.C. Alexander the Great founded the city named for him—Alexandria. About 280 B.C. the famed Pharus was constructed there by Sostratus of Cnidus—the earliest lighthouse known in history. It was about three hundred feet high, a three-storied structure; the lower story was square, the middle one octagonal, the upper one, which contained the light, circular and surmounted by a colossal statue of Poseidon (Neptune). The Pharus of Alexandria became widely known in the Islamic world, but Mohammedan authors erroneously attribute its foundation to the great world-conqueror himself, designating it Menarat Iskanderiah ("Lighthouse of Alexander"). They describe it as one of the marvels of the world. On the top of this lighthouse, they say, Alexander placed a magic mirror in which could be sighted all incoming ships, the country Rum (the Byzantine empire), the islands of the sea and whatever was done by the inhabitants. By virtue of this mirror, as long as it existed, the city of Alexandria was said to preserve its grandeur and power. The Persians called this lighthouse Mirror of Alexander (Aineh Iskenderi), believing that the fortunes of Alexandria depended on it, as it was a talisman con-

structed under the influence of a certain constellation. It is said to have broken to pieces shortly before the city was conquered by the Arabs in A.D. 641.

Rabbi Benjamin of Tudela, who traveled in the Orient between the years 1159 and 1173, mentions the high tower of Alexandria surmounted by a glass mirror by means of which the approach of a ship or a hostile fleet could be noticed even when it was a twenty days' voyage off. The city was therefore prepared for the reception of a hostile ship from whatever direction she approached. Once, however, when Greece was still subject to the Alexandrians, Benjamin continues, a Greek vessel cast anchor in the port of Alexandria. The captain, a Greek, Theodorus by name, instructed in all sciences, brought to the Egyptian king valuable presents of gold and silver, silk and purple. His ship was at anchor opposite the lighthouse. Every day the captain invited the guard of the lighthouse with his servants on board his ship until they were on friendly terms. One day he treated them to an opulent feast and filled them with wine till they were intoxicated and fell into a deep slumber. The captain then ordered his crew to smash the mirror, and set sail the same night. From that time onward Christian ships, small prowlers as well as large vessels, entered the port, and snatched away two large islands, Crete and Cyprus, which are still under Christian rule. Egypt was henceforward unable to resist the Greek power.

Leo Africanus, in his "History of Africa," writes that the mirror of Alexandria was of "steel glass" by the hidden virtue of which passing ships, while the glass was uncovered, should immediately be set on fire; but when the glass was broken by the Mohammedans, its secret virtue vanished.

The fame of Alexandria's Pharus and television mirror even spread to the Far East. Chao Ju-Kwa, who was stationed as inspector of maritime trade at the port of Ts'üan-chou in Fu-kien and collected there from the lips of foreign traders much interesting information on the countries of the Indian Ocean, which he published in his "Chu fan chi," written in A.D. 1225, gives a brief notice of Alexandria and its lighthouse. "On the summit of it," he writes, "there was a wondrous large mirror. In the event of a surprise attack by foreign warships they would be detected beforehand by this mirror, and the troops on guard duty were ready to meet the situation. In recent years Alexandria was visited by a foreigner who asked for work in the guardhouse of the tower and who was employed as a janitor. He was not suspected for years, when suddenly he seized an opportunity of abstracting the mirror and flung it into the sea, whereupon he disappeared." A late Chinese cyclopedia (*San ts'ai t'u hui*) has disfigured this tradition considerably by stating that Tsu-ko-ni (Alexander) erected in Egypt a temple on the top of which there was a mirror which when pirates of other countries made a raid reflected them and thus announced their arrival.

In the famous letter of Prester John (71) purporting to have been written by him to the Byzantine emperor, Manuel (1143–80), is described a marvelous mirror which is reached by ascending a hundred and twenty-five steps over an elaborate structure of pillars. In this mirror all plots and machinations and everything that was done in the adjacent and subjected provinces either on behalf of Prester John or against him would be clearly revealed and recognized; day and night it was guarded by twelve thousand armed men that it might not be broken by an accident. In the work of Johannes Witte de Hese (1389) this mirror of Prester John is also mentioned: three precious stones are deposited in it; one of these

directs and sharpens the vision; another, the senses; the third, experience; three very capable doctors have been elected to examine the mirror and see in it everything that is done in the world.

A "History of the World" published in Neo-Greek by Dorotheos, metropolitan of Malvasia, at Venice in 1763, alludes to a magic mirror in the imperial palace of Constantinople made by the emperor Leo the Philosopher: whatever existed or happened or was intended to be done in the world could be most clearly visualized in this mirror. The Emperor Michael, who was given to a voluptuous life, was informed one day by a messenger that he had beheld in the mirror the war preparations of the Turks against Constantinople. Michael, who just pampered at a banquet, did not like to be disturbed and ordered a servant to smash the mirror to atoms.

According to an Arabic tradition, Saurid was the wealthiest king on earth and had a mirror made from various alloys, wherein he could scan whatever occurred in the seven zones, whether good or bad, and what land was irrigated or not. This mirror was placed in the city of Amsus on the top of a green marble column. In the city of Sa on the bank of the Nile stood a pillar of white marble and upon it a mirror in which King Sa, for whom the city was named, was able to discern whatever happened in the seven zones.

Spencer, in his "Fairy Queen," has Merlin make a magic mirror in which a girl beholds the image of her swain. Walter Scott, in his "Lay of the Last Minstrel," relates that Cornelius Agrippa showed the Count of Surrey, during his sojourn in Italy, his sweetheart Geraldine in a mirror as she was reclining on a couch and reading her lover's poems by the light of a wax candle.

Nathaniel Hawthorne, in his story "Dr. Heidegger's Experiment," refers to a looking-glass hung in the doctor's room, "presenting its high and dusty plate within a tarnished gilt frame. Among many wonderful stories related of this mirror, it was fabled that the spirits of all the doctor's deceased patients dwelt within its verge, and would stare him in the face whenever he looked thitherward."

A SUBSTITUTE FOR ARSENIC

By S. MARCOVITCH

TENNESSEE AGRICULTURAL EXPERIMENT STATION

Don Marquis in his book "Archie and Mehitabel" puts the following words in the mouth of Archie the cockroach:

i am going to start
a revolution
i saw a kitchen
worker killing
water bugs with poison
hunting pretty
little roaches
down to death
it set my blood to
boiling
i thought of all
the massacres and slaughter
of persecuted insects
at the hands of cruel humans
and i cried
aloud to heaven
and i knelt
on all six legs
and vowed a vow
of vengence
i shall organize the insects
i shall drill them
i shall lead them
i shall fling a billion
times a billion billion

. . . .
come o mosquitoes
a billion billion strong
and sting a billion baldheads
till they butt against each other
and break like eggshells
. . . .
curses on the species
that invented roach poison

Evidently Archie and his cohorts are rebelling at chemical warfare, so that we humans may be assured that we have at least aroused fear in the hearts of our foes.

Without minimizing the importance of biological phenomena—as, for example, parasitism; the climatic checks of temperature and humidity, or cultural methods, such as time of planting and rotation of crops—we must place our main reliance in chemicals for keeping in subjection at least 80 per cent. of the insect pests.

The use of insecticides was stimulated by the appearance of the Colorado potato beetle in 1869, when the familiar Paris green came into vogue as a protective agent for phytophagous insects. The entire science of spraying and dusting of plants is, therefore, a development of the past forty or fifty years; and the last decade has witnessed a greater development of insecticides than all previous time. This has resulted in the creation of new chemical industries, such as the manufacture of calcium arsenate.

No sooner had the farmer been schooled in the use of calcium arsenate for protecting his cotton against the ravages of the boll weevil than a severe infestation (in 1923) made an unprecedented demand for calcium arsenate. All available stocks of calcium arsenate were soon exhausted. Prior to 1923 we were concerned in educating the farmer to dust his cotton, but now a new menace loomed on the horizon—a lack of poison. Well might our six-footed enemy rejoice over our lack of ammunition.

The price of arsenic doubled, or trebled. Mining engineers began scouting for new sources of arsenic. Much was written about the arsenic problem, the arsenic situation, the arsenic shortage and the manufacture of calcium arsenate. We were led into this dilemma because arsenic was the only stomach poison known that could be used as an insecticide. The need for a substitute was evident. The importance of the cotton crop, the increasing number of crop pests and the limited production of arsenic make it imperative that we have at least one other weapon by which to subdue the ravenous enemy. Our new weapon is sodium fluosilicate—first used in 1924 at the Tennessee Experiment Station for combating the Mexican bean beetle.

Exhaustive research work by the Chemical Warfare Service in 1926 and 1927 also demonstrated that sodium fluosilicate is more effective than calcium arsenate against the cotton boll weevil. These results led a prominent entomologist to remark, "We need have no fear that there is going to be any difficulty due to a scarcity of calcium arsenate. That bogey is gone and gone for good."

Comparative Toxicity Studies

As we all know, arsenic is a deadly poison to human beings, and this fact suggested its use as an insecticide. The next question was: What is the toxicity of sodium fluosilicate as compared with arsenic, to the lower as well as the higher forms of life? To determine this point, a series of experiments were initiated with mosquitoes, representing the invertebrates, and with rabbits, representing the vertebrates. Mosquito larvae proved especially well adapted for the purpose, since they are abundant, easily obtained or bred and live in a medium which lends itself readily to chemical changes of any desired concentration. Death of the larvae takes place

primarily by the oral ingestion of the chemical.

Sodium fluosilicate .01 molar (1–532) produced 50 per cent. mortality of the larvae of *Culex quinquefasciatus* within fifty-five minutes, whereas at the same concentration sodium arsenite required 135 minutes, sodium arsenate 390 minutes, and sodium fluoride 420 minutes. When the above chemicals were used against the grasshopper, *Melanoplus femur-rubrum*, in poison baits, sodium arsenite produced 89 per cent. mortality within forty-eight hours, whereas sodium fluosilicate gave 100 per cent. Similar results were secured with the cutworm, *Feltia ducens*. Poison baits with sodium fluosilicate were found to be distasteful to chickens. This is of considerable advantage when baits have to be used in the proximity of poultry or game birds.

The fluorine compounds were also studied on organisms lower than insects. With *Lumbricus terrestris*, sodium fluosilicate, sodium fluoride and sodium arsenite, in concentrations of 1–1000, required, respectively, 20, 40 and 240 minutes to produce a lethal effect. For protozoa, *Paramoecium caudatum* was used. A solution of sodium fluosilicate 1–10,000 is fatal almost instantaneously; sodium fluoride 1–1000 produced a kill within sixty minutes; whereas sodium arsenite seemed to be non-toxic. Similar results were secured with *Euglena viridis*.

The high toxicity of fluorine compounds for protozoa would suggest their usefulness against pathogenic forms. For this purpose one would have to use organic fluorides, the chemistry of which is but little known.

After the experimental work had shown that the fluosilicates were more toxic than the arsenicals to many of the lower organisms the next consideration was their relative toxicities to man and the higher animals.

The more extended use of fluosilicates as dusts on plants raises the question of the effects on human health when small quantities are ingested over a prolonged period, as well as the poisonous nature of a single large accidental dose. With rabbits, the minimum fatal dose of sodium fluoride by mouth was found to be 500 mg per kg, and for sodium fluosilicate 120 mg per kg. For comparison with arsenic, the soluble potassium arsenite required 14 mg per kg. To estimate the effect on man, we find that the minimum lethal dose would be thirty grams of sodium fluoride, 7.2 grams of sodium fluosilicate and .84 of a gram of potassium arsenite. Potassium arsenite is therefore about nine times as toxic to man as sodium fluosilicate and thirty times as toxic as sodium fluoride.

The cumulative and fatal action of very small doses of arsenic is well known. The evidence from various sources indicates that fluorine compounds in small daily doses may be administered over an extended period of time without fatal results. This aspect of the subject is of importance at the present time because the small arsenical residue found on apples is considered objectionable by various agencies. Apple growers are therefore demanding a substitute for lead arsenate to be used as a spray for the codling moth. Since sodium fluosilicate is acid and slightly soluble it is not compatible with the fungicides now in use, and can not as yet replace lead arsenate. Efforts are being made, however, to devise a fluorine spray material that will be safe on foliage and toxic to insects.

How Fluorine Compounds Kill Insects

Most insects are so greedy that they do not hesitate to swallow arsenic on foliage. In recent years we have found many other insects that do not succumb to the foliage dusted or sprayed with an

arsenical. These are more dainty in their dietary habits and refuse to eat other than clean foliage. This is known as the repellent effect of arsenic on such insects as the Japanese beetle, blister beetles, cucumber beetles and flea beetles.

Professor Baerg, of the Arkansas Experiment Station, as well as Mr. Ingram, of the United States Bureau of Entomology, has found that blister beetles may be killed by sodium fluosilicate. To quote from Mr. Ingram's report:

> Calcium arsenate, Paris green and lead arsenate have been tried as dusts and as sprays at varying strengths, but in all cases these merely drove the beetles away, which would not eat the poisoned leaves. Sodium fluosilicate has proved to be the best remedy. The beetles die, not from eating the poisoned foliage, but from getting the poison on their feet and then raking their feet through the mouth to get the irritating stuff off.

G. D. Schafer was the first to discover the irritating properties of sodium fluoride on roaches. Those insects that have the "cleaning-up" habit are very easily fooled into taking the powdered fluorides into their mouths. For this reason dry dusts are more effective than sprays, since the latter form a varnish-like coating.

After the fluorine is absorbed by the insect, the precipitation of essential calcium from the tissues is effected. The meager calcium content of the lower organisms may account for their easy susceptibility to fluorine compounds.

Source of Sodium Fluosilicate

It is of interest to note that sodium fluosilicate is made from phosphate rock, the same material which also furnishes us with fertilizer. Phosphate rock contains about 3 per cent. calcium fluoride and some silica. When sulphuric acid is added to phosphate rock for the purpose of making acid phosphate, fumes are liberated. Formerly these fumes were allowed to escape, but as they were very injurious to vegetation, laws were enacted requiring that the gases be confined. The silicon tetrafluoride gases are now conducted into towers with dripping water, forming fluosilicic acid. In most cases this acid is not saved, but is allowed to drain away. When sodium chloride is added to fluosilicic acid, sodium fluosilicate precipitates out. As there are no extensive uses for by-product fluosilicic acid, probably 95 per cent. is discarded. The commercial sodium fluosilicate is dense and not particularly adapted for dusting. A light, fluffy sodium fluosilicate is now being manufactured more suitable for dusting operations on plants.

As the manufacture of sodium fluosilicate becomes standardized, and its uses become better known, every farm home and even the city dweller will have a supply of sodium fluosilicate. When Archie has a vision of our entire human population thus prepared to annihilate the race of the six-footed, no doubt he will throw down his arms, raise the flag of truce and surrender, as he might well do.

RABBIT FEVER OR TULAREMIA

By WILL C. BARNES

ON Thanksgiving Day, 1927, a United States naval surgeon, well known in medical and social circles in the city of Washington, accompanied by his brother, visited the family farm in central Virginia for a holiday rabbit hunt. Rabbits were fairly plentiful and the two men had several very successful days' sport.

Soon after his return to Washington the naval officer went to the U. S. Naval Hospital suffering from severe headaches accompanied by a high temperature and chills, with terrific pains in every part of his body. Also, the glands in his arm pits were greatly enlarged and very sore. In spite of all that medical science could do he died within fifteen days.

Meantime the brother, suffering from the same symptoms, had been taken to a hospital in Charlottesville, Virginia, where he was a very sick man for several weeks but eventually recovered.

The sickness was diagnosed by Naval Hospital surgeons as rabbit fever, or tularemia, a comparatively new disease to the medical fraternity, considered as some form of low fever and treated accordingly.

The death of the naval surgeon, however, attracted wide attention to the trouble, and many persons learned for the first time that there lurked in the body of little old "Peter Rabbit" the germs of a disease for which to date there has been found no cure and from which the death loss is big enough to challenge the best ability of the medical world to discover a remedy.

HISTORY OF THE DISEASE

The history of the discovery of this new and in many respects mysterious disease is an interesting chapter in medical research.

In 1907 the late Dr. Ancil Martin, of Phoenix, Arizona, had a number of patients who were suffering from some eye trouble quite unlike anything he had ever seen. Down that way trachoma is a very common disease of the eyes, especially among the Indians. Dr. Martin was an expert on that trouble, but his tests for trachoma gave negative results. He found the symptoms very similar to typhoid fever but with ulcers on the eyes and hands. The cases ran for from four to six weeks, one for three months or more. Each gradually recovered. The history of every case showed that the patients had been handling the common western jack-rabbit (*Lepus californicus*). There was at that time, 1907–8, a bounty on jack-rabbits due to their inroads upon the alfalfa fields of the farmers near Phoenix. Farmers were unable to raise any crops at all on a strip several hundred feet wide along the line of the desert. The hungry jacks took every green thing growing. Hence rabbit drives were very common. Thousands of these long-eared speeders were rounded up and driven into pens or corrals like sheep and cattle, there to be killed by clubs. Many of the animals were skinned and used for home consumption and more commonly as food for hogs. For want of a better name for the new-found disease, Dr. Martin called it "rabbit septicemia," caused by a new and at that time undescribed organism.

Pursuing his investigations into this peculiar disease, Dr. Martin wrote to a well-known authority, Dr. Novy, of Ann Arbor, Michigan, describing the cases.

The letter, a copy of which recently came into the author's hands, is in part as follows:

Phoenix, Arizona Territory,
Sept. 19, 1907.

DR. FREDERICK G. NOVY,
ANN ARBOR, MICHIGAN.
Dear Doctor:

There have been during the summer several individuals in this locality who have suffered from an infection as a result of skinning and dressing wild rabbits. They were of the so-called "Jack" variety. Three of these persons have had their primary lesions in or about the eye. Small abscesses formed on the lids and on the bulbar conjunctiva as well.

At the onset there were chills, profuse sweating and an elevation of temperature of from two to five degrees with rapid pulse lasting several days. There were no deaths.

Yours truly,
ANCIL MARTIN.

These cases reported by Dr. Martin are absolutely the first on record for the discovery of this disease in human beings and the organism isolated and studied.

THE NAME TULAREMIA

The scene now changes to Southern California in the year 1910. At that time California was engaged in a war of extermination against the common ground squirrel of the Pacific Coast, believed to harbor and transmit to man bubonic plague by means of fleas found upon the animals. Besides this, their raids upon the farmers' crops were estimated to destroy annually fully twenty million dollars' worth of California farm products. On both counts they were "persona non grata" in the highest degree.

These ground-squirrels were especially numerous in the vicinity of the once great Tulare Lake, in Tulare County, California. In 1910 men at work in that region reported the squirrels to be dying in large numbers from some fatal epidemic. The surgeons of the U. S. Public Health Service who were fighting the ground-squirrels, scenting a possible natural ally in their extermination, sent two Public Health Service surgeons, Drs. G. W. McCoy and C. W. Chapin, post-haste to Southern California to investigate and report on the rodents' misfortunes. These men found the squirrels being decimated rapidly by some, to them unknown, bacterial disease. They worked out its progress through captured squirrels and finally isolated a new causative organism. This they called "Bacterium Tularense" from the fact that the region of greatest infection seemed to be upon the bed of the reclaimed lake which, due to the presence of thousands of acres of the reed or bulrush called "Tules" by the early Spanish settlers, was called "Tule Lake," also the county "Tulare." Hence they coined a brand-new word "Tularense" and fastened it on to this new bacterial pest.

At that time they knew nothing of Dr. Martin's discoveries of several years before. The medical world was not informed of the Arizona cases until some years later.

SHALL IT BE CALLED MARTIN'S DISEASE?

McCoy and Chapin published the results of their investigations early in 1912. Several years later, Dr. Edward Francis, also of the U. S. Public Health Service, looking around for a name for this new peril to the human race, accepted Surgeon McCoy's name and called the disease "Tularemia."

At the meeting of the Arizona State Medical Association, on April 26, 1926, Dr. Martin read a paper on "Tularemia" in which he gave the foregoing history of his cases, dating back to 1907, long before the investigations and discoveries of McCoy and Chapin. He quoted a personal letter from Surgeon Francis written in April, 1925, which said in part, "Your case reported to Dr. Novy in 1907 places you in the position of being the 'Father of Tularemia.'" At a meeting of the Southwestern Medi-

DR. EDWARD FRANCIS

OF THE UNITED STATES PUBLIC HEALTH SERVICE TO WHOM THE AMERICAN MEDICAL ASSOCIATION RECENTLY AWARDED ITS GOLD MEDAL FOR HIS "THOROUGH AND IMPORTANT SCIENTIFIC CONTRIBUTIONS TO THE KNOWLEDGE OF TULAREMIA."

cal Association, held at Dallas, Texas, in 1926, it was proposed to call it "Martin's" disease after the original discoverer of its causative agent in 1907.

THE DISEASE ELSEWHERE

In 1919 reports came to the Public Health Service in Washington of a new and peculiar disease in the state of Utah known locally as "deer fly fever," "tick fever," etc.

Dr. Francis was sent to Salt Lake to investigate. In southern Utah he found a large number of people suffering from some unknown cause, followed by a number of deaths. The local doctors had been treating the patients for blood poisoning, ulcers, septic infection, typhoid. Nearly all the patients complained of severe pains in the back, swollen glands, terrific headaches. Many had huge repulsive ulcers, generally on their hands, sometimes at other places. No progress whatever had been made in curing the sick ones. Nothing seemed to help.

A review by Francis of a large number of cases proved that the majority of the persons suffering had been handling jack-rabbits previous to their sickness. They were mostly farmers and Indians who had taken part in jack-rabbit drives, then a popular outdoor sport in that region.

From a man suffering from ulcers and other symptoms, Francis took some blood with which he inoculated some guinea-pigs brought with him from Washington.

These at once showed all the symptoms of being infected with Bacterium tularense. Most of them died within a few days after their inoculation. Worst of all, Dr. Francis himself came down with the disease and suffered from all the symptoms he had been observing in others. Leaving further investigations to his assistants, he went back to Washington and into the Naval Hospital a very sick man. Others carried on the Utah studies and determined beyond all doubt that the disease was tularemia and that it was due largely to handling wild rabbits. They tried all sorts of odd experiments, did those surgeons. Many of the Utah sufferers claimed they became infected by the bites of deer flies. They captured a number of these flies and by careful handling caused them to bite a number of captive rabbits and guinea-pigs, that as far as could be determined were perfectly healthy. Within five or six days these bitten rabbits and pigs began to die. Dissection showed every symptom of tularemia.

They reversed their experiments by taking fluid from one of the dead guinea-pigs and placing a few drops of it on various parts of live rabbits. The rabbits began to die in a few days and again dissection showed the presence of the deadly bacilli tularense.

Their research work took the surgeons of the Public Health Service all over the country. In Montana they found a farmer suffering from a bad case of infected eyes. His blood showed bacilli tularense. Then he recalled one day when he was harnessing his horses he picked several large "ticks" from their shoulders. Later he remembered he rubbed his eyes with his fingers. There was no doubt as to the means of his infection and thus a new source of danger was found. Tick fever turned out to be tularemia. Fifteen hundred miles distant, in Cincinnati, Ohio, a Public Health surgeon, Dr. Wherry, found a white butcher and a colored cook suffering from what local physicians had diagnosed as "glanders," a very dangerous communicable disease, generally confined to horses, but occasionally found in humans. He promptly proved it to be tularemia in its worst form. The butcher had handled rabbits in his shop and the cook had dressed them in the kitchen.

The disease is now fairly prevalent in every state of the Union except Wash-

ington, Wisconsin, Delaware, New York and the New England states. It will doubtless eventually be found in all of them. The opinion has been expressed that it is already in them but has not as yet been definitely located and diagnosed.

In 1925, Japanese surgeons reported it as prevalent in that country due to infections from rabbits.

The odd thing about it is that, although the disease was discovered and diagnosed among the ground-squirrels in California as early as 1911, not a single case in a human being has as yet been reported from that state, according to Dr. Francis, who is an authority on the disease. Is it the climate of the Golden State acting in a new rôle?

A Case of Cause and Effect

For many years the unaccountable ebb and flow in numbers of the wild rabbits in several localities has been observed by biologists and sportsmen. For a few years cottontails will be very plentiful. Then suddenly, for no known reason, there is a notable scarcity of them and hunters return with empty game bags.

On one of the national forests in a northern state, snowshoe rabbits were becoming so numerous and so far-reaching were their ravages on the young pine seedlings which the government foresters were nursing along towards saw logs that a campaign of elimination was about to be inaugurated in order to save the trees. About that time the forest rangers began to note an unaccountable scarcity of these rabbits. As the scarcity became more and more evident the foresters thanked a kindly providence for some unknown influences that saved them from the thankless and decidedly unpopular task of killing the rabbits off.

In several western states the long-legged, long-eared jacks accumulated in such vast numbers that the settlers were demanding that a bounty be paid by the state on the speedy pests as well as the holding of jack-rabbit round-ups everywhere. Before this could be done their numbers were reduced to a point where repressive measures were deemed unnecessary—all these reductions without any outward signs or reasons. Biologists now feel that the reduction in numbers was unquestionably due to tularemia, which in some manner became epidemic among the rabbits and cleaned them out, one of Dame Nature's odd ways of meeting a difficult situation.

One wonders why it would not pay the authorities in Australia to import a few thousand American bunnies and see what effect it would have on the immense numbers of rabbits that cause such heavy losses to farmers and stockmen down that way, even after the expenditure of millions of dollars, year after year, in various ways calculated to discourage large families and long life among rabbits in that country. Perhaps here is the cure for their troubles.

Deaths from Tularemia

A large number of cases of tularemia in humans have been reported from various parts of the United States. Out of five hundred listed cases, where the disease was diagnosed with certainty, twenty died—a 4 per cent. loss, which is a sufficiently high death-rate to classify tularemia as a serious matter.

If the suffering, expense and loss of time is taken into consideration, it becomes even more serious. Few recover quickly. It is generally a matter of from four to six weeks away from work or business. Out of a family of four, Dr. Francis reported that three died. Out of 311 cases investigated in one year, 235 were males, seventy-six females. Out of 420 reported cases from various parts of the south, only eighteen were Negroes. Out of these 420 cases, seventeen, or 4 per cent., terminated fatally.

Sources of Infection

While the large percentage of cases have come from handling wild rabbits, which is far and away the most dangerous source of infection, a number of infections have come from other animals.

Nearly all the squirrel and rodent families have been found guilty, while it occasionally has been definitely traced to the bites of some of the common domestic animals, such as dogs, cats and, in one case, a hog. These animals, however, undoubtedly became infected in their mouths through eating diseased rabbits.

Francis reports only one known case of the transmission of the disease from human to human. This was where a mother dressing an ulcer on her son suffering from tularemia accidentally pricked her thumb with a pin, thus carrying the infection to her own blood.

Practically every investigator who has studied the disease and made examinations of diseased rabbits or guinea-pigs through post-mortems has contracted it. No deaths have followed among them, however.

It was believed at first that rubber gloves were a satisfactory safeguard. The trouble has occurred, however, when rubber gloves and every other precaution were taken against it.

The insidious nature of the infection can be best understood when it is known that a few drops of fluid from an infected rabbit have been placed on the palm of a man's hand on which there was no observable injury to or break in the skin and the man came down with tularemia inside of a week.

To date, no protective vaccine or serum has been discovered, nor has there been developed any drug that is of use in alleviating the sufferings of victims of tularemia. It seems to be a disease in which man is practically helpless and nature must be allowed to work out her own unchecked processes.

Once Sick Always Immune

It has been proven conclusively, however, that sufferers who recover are always immune to future infections and can handle diseased rabbits without danger. Nevertheless, Dr. Francis and his assistants in the Public Health Laboratory who have nearly all contracted tularemia take no chances in handling the hundreds of rabbits and guinea-pigs they have there in various stages of the disease. So far, the trouble is confined wholly to wild rabbits. No cases have ever been reported among tame rabbits, such as Belgian hares raised in rabbitries.

Spread of Disease

A study of the development of tularemia indicates rather clearly that it has spread with considerable speed all over the country. In all probability its origin will eventually be traced to the ground-squirrels of the Pacific coast. From there it has probably been carried by shipments of diseased rabbits to different parts of the country, alive and dead. The wild jacks captured in countless numbers by drives all over the west have been shipped to various sections of the country as food, for both humans and animals.

Again, great numbers of the ordinary cottontail rabbits are shipped constantly from such western states as Kansas and Nebraska to almost every eastern state to restock hunting areas, farms and estates for sporting purposes. Over fifty thousand cottontail rabbits were imported into one single eastern state from the west in 1927 to stock such areas. Quite as many more were sent to the same state for feeding foxes on large fox farms. Is it any wonder the disease has spread?

Many Rabbit Hunters

The state game warden of Pennsylvania recently stated that of the six hundred thousand licensed hunters in that state probably 80 per cent. were rabbit

hunters. In the southern states, where little Peter Rabbit is a welcome addition to the family menu, the percentage is undoubtedly even higher.

How to Recognize the Disease

If you are anxious to see whether or not a certain rabbit has tularemia, examine its liver and spleen. If these organs are covered with small white specks about the size of a pinhead, it had tularemia. These spots are the one unfailing test of the disease. Lacking them, the rabbit is probably perfectly healthy. Rabbit meat when cooked may be eaten without any danger, while rabbits infected with the disease if held in a frozen state for thirty days are perfectly harmless when cooked and eaten.

"Most of the cases among humans," according to Dr. Francis, "are self-inoculated. A market man skins and prepares rabbits for his patrons. A wife or servant dresses one for the family meal. A hunter kills one and cleans it right on the spot. A farmer pulls an infected tick from his horse, then rubs the finger in his eyes. These are the common means of infection."

Bedbugs are known to have caused the disease in guinea-pigs. Doubtless, they would also transmit it to humans.

Taking it all around, this disease seems to be one that is here to stay. It probably has been with us for many years, but until recently was not recognized in its true character.

Millions of cottontail or jack-rabbits are killed as food every year and the loss to the public, if they are not to be eaten, will run up into large figures.

On the other hand, the losses to the individual that follow the attack—the losses in time, and costs of doctors' bills —will far overrun the loss of meat. The worst of it all is that a young cottontail properly cooked is just about the most toothsome morsel in the way of game that the average American can secure.

It is but fair to explain, however, that only a small percentage of the rabbits offered for sale in the public markets are affected by tularemia. For example, Dr. Francis examined the livers of one thousand rabbits offered for sale at the various markets in the city of Washington and only found nine, or slightly less than one per cent., infected with the disease. At the same time, out of twenty-two local patients suffering with tularemia every single one had handled or dressed wild rabbits shortly before his sickness.

It will be hard to wean our people away from the use of rabbit meat. Millions will "take a chance" and use it. More's the pity; they will doubtless be the poorer classes, ignorant of the danger they are running and who also can ill afford the loss of time and the expense due to sickness.

A Few Don'ts

Don't touch or use a wild rabbit that seems dull, dopey, glassy-eyed, slow-moving or with rough, ragged fur.

Don't fail to shoot such rabbits or those that won't run from you on sight. When killed, either burn or bury them, lest dogs or cats contract the disease by eating the carcass.

Don't use a rabbit or handle one caught or killed and brought home by the children or family dog. They were probably too sick to run from them.

Don't handle or touch a wild rabbit, unless with rubber gloves. Even then, carefully disinfect your hands afterwards.

And finally, if you have been doing any of these "don'ts" and a few days later, out of a clear sky, suddenly develop a frightful headache, are racked with pains in every bone, your temperature is high, with frequent chills, there is a huge swelling under an armpit, and you feel sick and miserable all over, go to bed and send for the doctor. Ten to one he will find you have tularemia.

Underwood and Underwood

THE MEDICAL CENTER AT NIGHT

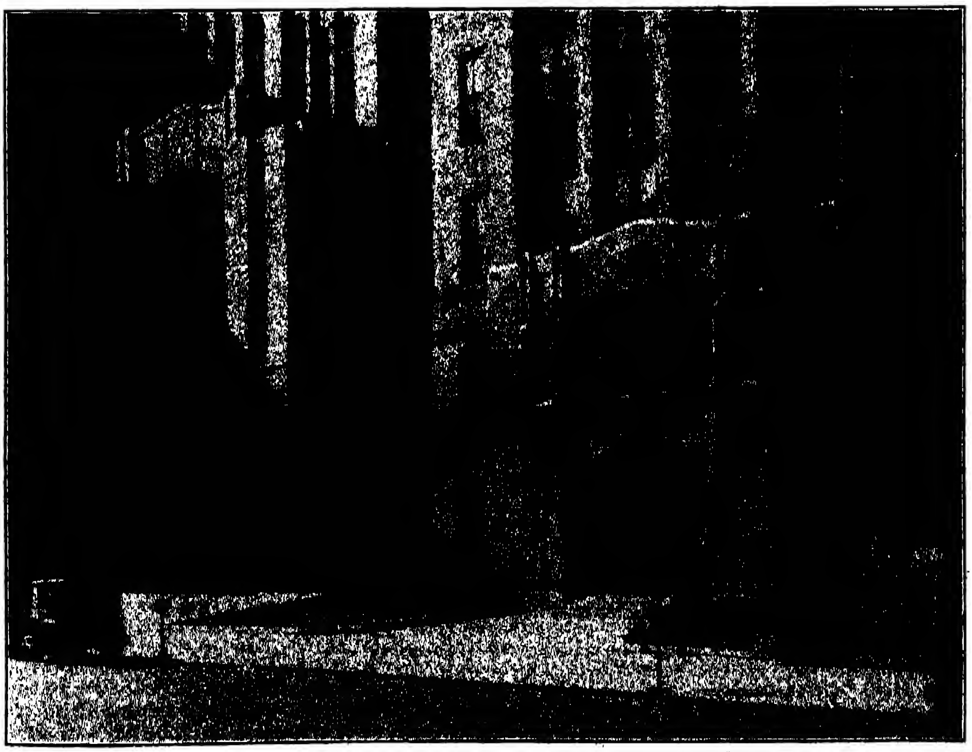
THE BUILDING AT THE EXTREME LEFT IS THE NEW YORK STATE PSYCHIATRIC INSTITUTE AND HOSPITAL; THE NEUROLOGICAL INSTITUTE IS NEXT, THEN THE ANNA C. MAXWELL HALL, THE RESIDENCE OF THE PRESBYTERIAN HOSPITAL TRAINING SCHOOL. THE GROUP BUILDING ON THE RIGHT HOUSES THE STEPHEN V. HARKNESS PAVILION; THE COLLEGE OF PHYSICIANS AND SURGEONS; THE PRESBYTERIAN HOSPITAL; THE SLOANE HOSPITAL FOR WOMEN; THE SQUIER UROLOGICAL CLINIC; THE BABIES' HOSPITAL; THE VANDERBILT CLINIC AND THE SCHOOL OF DENTAL AND ORAL SURGERY.

THE PROGRESS OF SCIENCE

THE MEDICAL CENTER OF NEW YORK CITY
A THREE-FOLD ACHIEVEMENT IN COOPERATION

Research—teaching—the care of the sick—these three fundamentals of modern scientific medicine have now been brought together and unified at the Medical Center. Towering above the Hudson, an architectural landmark even in a city of skyscrapers, the Medical Center has been functioning since early spring as a hospital, but not until the present fall term has it entered upon its work as a medical university and as a great research laboratory.

The formal dedication to its three-fold purpose on October 12, with academic procession and the conferring of honorary degrees on citizens identified with the movement—Messrs. Edward F. Harkness, Dean Sage, James Gamble Rogers and Otto Marc Eidlitz—celebrated an accomplished fact, no longer a "project." For with the installation within its walls of the College of Physicians and Surgeons, the De Lamar Institute of Public Health, the School of Dental and Oral Surgery and the School of Oral Hygiene—teaching groups of Columbia University—the Medical Center had definitely rounded out its



—*Photograph by R. S. Grant*

ENTRANCES TO THE MAIN BUILDINGS

SHOWING CLEARLY THE JUXTAPOSITIONS OF THE ASSOCIATE INSTITUTION. THE ENTRANCE ON THE LEFT IS THAT OF THE PRESBYTERIAN HOSPITAL, THE SLOANE HOSPITAL FOR WOMEN, AND THE SQUIER UROLOGICAL CLINIC. THE ENTRANCE ON THE RIGHT IS TO THE COLLEGE OF PHYSICIANS AND SURGEONS AND THE VANDERBILT CLINIC.

Underwood and Underwood

THE LIBRARY OF THE COLLEGE OF PHYSICIANS AND SURGEONS.

functions, becoming an educational institution for advanced study and research, as well as a unique assemblage of hospitals and clinics. The advantages which accrue—on the one hand to the patient, on the other to faculty and students—from this proximity and interrelationship of hospital, clinic, school and laboratory are self-evident and far-reaching.

Of special interest from a professional viewpoint is the fact that for the first time in New York City are now brought together in one building a dental school and a medical school, with their students having many courses in common. This marks a distinct step toward an ideal long held by leaders in dentistry—the recognition of this science as a department of medicine and the establishment of standards of dental teaching comparable to those of medicine.

That groups for study and research in dietetics, in nursing, and in social service are also housed at the Medical Center emphasizes anew its significance as a great cooperative achievement, a significance repeatedly stressed in the recent ceremonies, both by word of mouth and by the personnel of participants and guests, representing many fields of scientific and educational endeavor.

Appropriately, the address of dedication was delivered by Dr. Samuel W. Lambert, dean emeritus of the College of Physicians and Surgeons, and president of the New York Academy of Medicine. His association with the Medical Center movement goes back eighteen years to the time when Columbia University and the Presbyterian Hospital first entered into an agreement whereby the latter became the teaching hospital for the College of Physicians and Surgeons. From that beginning

OPERATING AMPHITHEATER, WITH 149 SEATS

THERE IS A RADIO PHONE ATTACHED TO EACH SEAT SO THAT THE HEART BEAT OF THE PATIENT ON THE TABLE CAN BE PLAINLY HEARD BY THE STUDENT. ONE OF THE FEATURES OF THIS OPERATING ROOM IS THE X-RAY VIEWING MACHINE SO THAT THE SPECTATORS CAN FOLLOW THE OPERATION AS IT PROGRESSES. THE TILING IN THIS ROOM IS GREEN. THIS DOES AWAY WITH GLARE AND IS EASIER ON THE EYES OF THE ATTENDING PHYSICIANS.

came ten years later the formation of the Joint Administration Board to organize a complete Medical Center.

To-day the cooperating institutions include, besides the teaching groups already mentioned, the New York State Psychiatric Institute and Hospital, Presbyterian Hospital of New York, Presbyterian Hospital School of Nursing, Squier Urological Clinic, Harkness Private Pavilion, Neurological Institute of New York, Babies' Hospital of New York, Sloane Hospital for Women and the Vanderbilt Clinic. Each of the units retains its identity while cooperating in the purposes of the center. And all are now housed on its twenty-acre campus with the exception of the New York State Psychiatric Institute, the Babies' Hospital and the Neurological Institute whose buildings are under construction.

That the Medical Center, while functioning in its threefold aspect, is by no means a finished project, lends an enduring and forward-looking interest to its activities. Not only has space been allotted for the expansion of the present buildings and for projected residences and recreational halls for the staff, but there is also provision for additional buildings which may be called for by future discoveries and development in science. To open doors of opportunity for coming generations has been the object of its planners—as well as to make the maximum contribution to the welfare of the present. For these ends, the perfection of its buildings and equipment, outstanding as are both, is secondary to the idea which they represent—the union of all the elements of medicine and related sciences for the benefit of mankind—along the three lines of endeavor, teaching, research and the care of the sick.

THE INSTITUTE OF CHEMISTRY

The second session of the Institute of Chemistry of the American Chemical Society concluded its four weeks' session on August eighteenth at Northwestern University, Evanston, Illinois. It will be recalled that the first session was held at State College, Pennsylvania, in 1927, where four hundred and fifteen were registered for the various sessions. The second session had a registration of six hundred and thirty three, not including those who attended single lectures. Of these the majority came from industry, only one hundred and fifty-five being identified with the teaching profession. A large number attended single lectures, and in addition the public was welcomed to the less technical lectures of the evening.

The plan of the Institute is to provide programs to engage the entire time of those so inclined, but composed of units to enable those who wish to combine recreation with their institute activities to take as little or as much of each day's offering as he may care to without losing continuity of thought or argument as would otherwise be the case. The effort is also made to so arrange the program as to serve the needs of chemists of various experience. In particular, the institute is a place where the present status of special fields in the science may be related by those expert in those fields, and where discussion may go on leisurely in the absence of crowded programs or too diverse attractions.

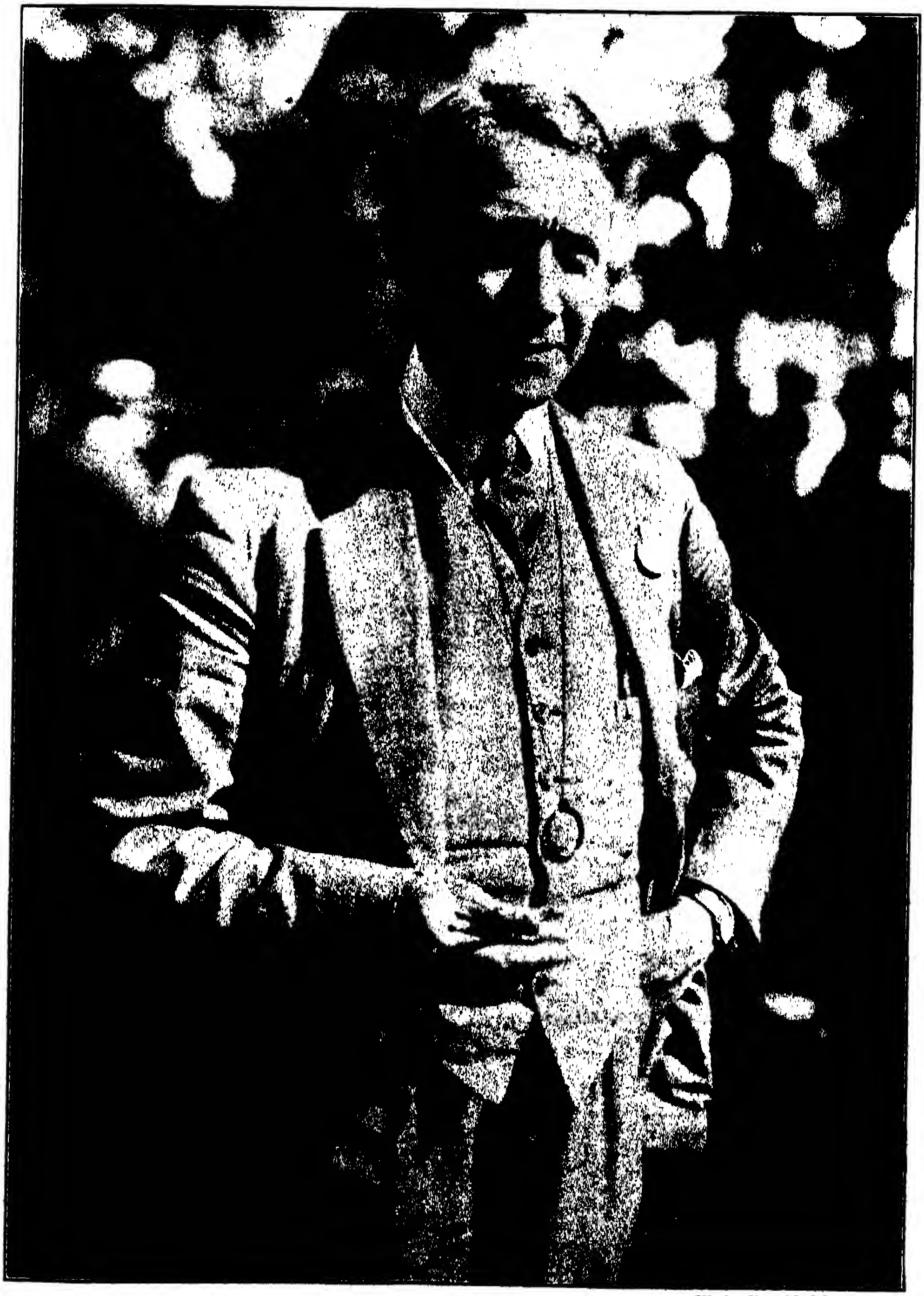
Geographically, people came from nearly every state in the Union, from Canada, Scotland, Norway and the Philippines.

The program, while not neglecting theoretical chemistry, nevertheless tended to emphasize applied chemistry. The first week was especially devoted to agricultural problems having a chemical approach. On each of five evenings

Wide World Photograph

SOME OF THE DISTINGUISHED CHEMISTS PRESENT AT THE MEETINGS

AT THE SESSION. L. TO R., CHARLES L. PARSONS, SECRETARY OF AMERICAN CHEMICAL SOCIETY; H. N. HOLMES, PROFESSOR AT OBERLIN COLLEGE; S. W. PARR, PRESIDENT, A. C. S.; SIR JAMES IRVINE, PRINCIPAL OF THE UNIVERSITY OF ST. ANDREWS, SCOTLAND; H. E. HOWE, EDITOR OF *Industrial and Engineering Chemistry*, AND G. M. ROMMER, OF THE U. S. DEPARTMENT OF AGRICULTURE.



Wide World Photograph

SIR JAMES IRVINE

GUEST OF HONOR AT THE SESSION OF THE INSTITUTE OF CHEMISTRY.

of the week motion picture programs were offered, followed by a popular lecture. Special industrial trips were taken to the Argo plant of the Corn Products Refining Company, to the North Side and Des Plaines sewage treatment works of the city of Chicago, Sherwin-Williams Company, Universal Portland Cement Company, the Whiting refinery of the Standard Oil Company of Indiana, the laboratory of the Universal Oil Products Company at Riverside, Illinois, and the Hawthorne Works of the Western Electric Company. A party of forty-five were the guests of E. B. Frost, director of the Yerkes Observatory, on one of the Sundays.

Recreation was not overlooked in an otherwise heavy program, and many enjoyed golf, tennis and swimming. Each evening an informal mixer or social gathering was held at Willard Hall, and on these occasions in addition to popular diversions there were informal discussions and motion pictures as well as special talks on several occasions. These included a vivid portrayal of the life at St. Andrews by Sir James C. Irvine, the honor guest of the institute, a discussion of the problems of a chemistry teacher in China by Earl Otto who served for four years as a teacher in the Orient and the recitation of Anglo-Norwegian dialect poems by Louis N. Crill, secretary of agriculture of South Dakota.

The scheduled speakers numbered one hundred and eighteen and some of these appeared more than once on the program, besides broadcasting radio talks over WGN and appearing upon request before several luncheon clubs and other organizations in the vicinity of Evanston and Chicago. The sessions attracted the attention of the daily press, through which many thousands had awakened a new interest in chemistry in its several relations to everyday affairs.

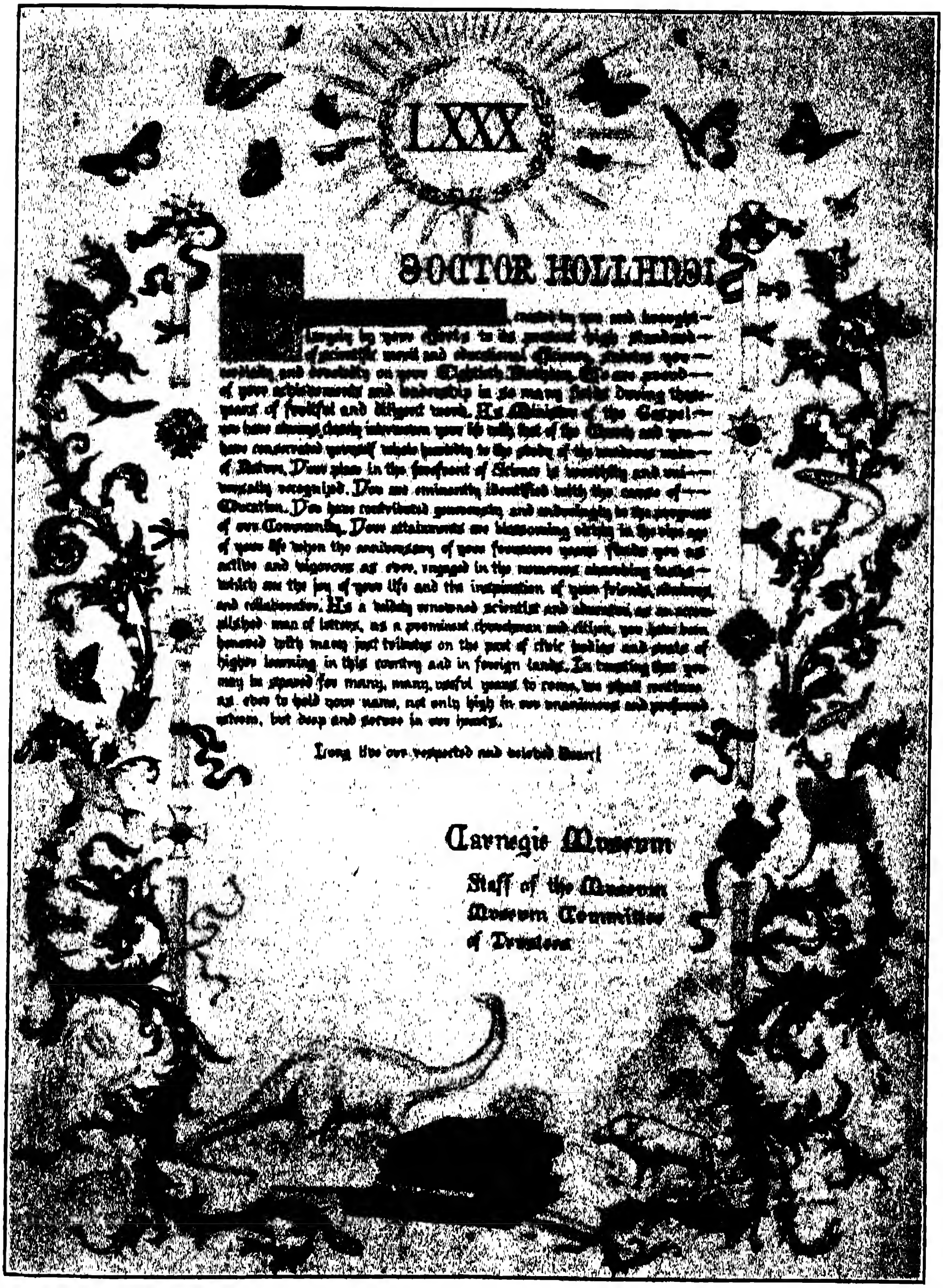
It is yet to be determined whether the institute will hold a third session in 1929, the first two being the only ones thus far authorized by the Council of the American Chemical Society. The future of the institute came before the Council at the seventy-sixth meeting of the society held at Swampscott, Massachusetts, from September 10 to 14, 1928. It will also be necessary to find financial support if the experiment is to continue and be developed into a permanent annual activity.

ULTRA-SOUND WAVES IN BIOLOGY

Dr. E. Newton Harvey, professor of physiology at Princeton University, and Alfred E. Loomis, of the Loomis Laboratory, of Tuxedo Park, New York, are producing, and applying to biological research, supersonic waves which oscillate so rapidly that they can not be heard by the human ear.

When a flat disc cut from a quartz crystal is compressed in a certain direction with reference to the crystal axis, one side will become charged positively, and the opposite side will become negatively charged. This is the piezo-electric effect. Conversely, if the crystal disc is placed between two plates properly charged, the crystal will be compressed. On reversing the charges the crystal expands. The compressions and expansions travel through media in contact with the crystal as sound waves which may be given very high frequencies by the proper oscillating device. Each crystal disc has a natural vibration period of its own, depending on its thickness.

The supersonic waves—the ultra-violet of sound—are produced by a miniature radio broadcasting apparatus which causes the quartz crystal to vibrate. The apparatus is operated on 110-volt alternating current and em-



TRIBUTE TO DR. HOLLAND

ILLUMINATED MANUSCRIPT PRESENTED BY THE CARNEGIE MUSEUM TO DR. W. J. HOLLAND ON THE OCCASION OF HIS EIGHTIETH BIRTHDAY WHICH OCCURRED ON AUGUST 16, DURING THE SESSIONS OF THE FOURTH INTERNATIONAL ENTOMOLOGICAL CONGRESS AT ITHACA.

ploys a 75-watt tube with two small transformers. The apparatus has been so devised that the quartz crystal, the producer of the supersonic waves, can be placed on the stage of a microscope with the specimen to be studied above it in the direct path of the waves. In this way it has been possible for the first time to examine the effect of the ultra-sound waves upon cells.

The characterization of high-frequency sound waves (or supersonics) as the "ultra-violet of sound" is an indication of the relationship which these bear to the sound waves we more frequently encounter. The two departures from the ultra-violet—to spoil the analogy as early as possible—must not be lost sight of. They do not pass through a vacuum (which emphasizes their chief relationship to ordinary sound waves) and apparently they do not stimulate specialized tissues like muscle and nerve. In this latter respect they differ from certain bands of the electromagnetic spectrum (*e.g.*, radiant energy and electricity). But one wonders whether some sensitization will not be effected so that it is possible to stimulate sensory tissues, ere the task is done. Two frequencies have been used—400,000 and 1,200,000 vibrations per second.

Observing under a high-power microscope, it has been possible to follow the progressive destruction of frog blood corpuscles. The oval cells at first become warped and twisted. Strained areas appear and the color fades, leaving a pale distorted shadow. Individual bacteria can be studied, but while they can be violently agitated their destruction under the microscope has not been observed.

If a fine emulsion of oil is examined an individual droplet of oil can be singled out and made to rotate rapidly in either direction at speeds that can be accurately controlled by varying slightly the frequency of the oscillating circuit.

An excellent material to illustrate the effects of these waves is a leaf of Elodea, which is two cell layers thick. The protoplasm with suspended chloroplasts forms a thin layer about the cellulose cell wall enclosing the vacuole of cell sap. High-frequency sound waves of low intensity passed through these cells cause the protoplasm to rotate very much as in the normal rotation or cyclosis of Elodea. Increasing the intensity increases the movement until the whole cell is a rapidly whirling mass of protoplasm, fragments of which are torn loose and rotate as small balls in the vacuole. The effect is very striking and might almost lead one to conclude that the normal cyclosis of this plant was caused by high-frequency vibrations. The normal protoplasmic rotation of Elodea is stopped by the waves unless they are of very low intensity. Rotation begins again provided the raying has not been too strong. Sugar plasmolysed Elodea cells are affected in the same manner as are the unplasmolysed ones, the whole protoplasm rotating rapidly, until, with increasing intensity, the mass finally bursts and scatters the chloroplasts, still whirling, throughout the cell. Nitella cells when rayed have the chloroplasts torn from the walls of the cell and whirled rapidly, leaving a clear area which had originally been a uniform green color.

No effects of the waves have been noted that could be clearly traced to an influence on chemical processes in cells, although it is known that high intensity waves influence certain chemical systems, especially metastable ones. The phenomena in living organisms, apart from temperature rise, are connected with mechanical effects, the most striking of which might be best described as "intracellular stirring."

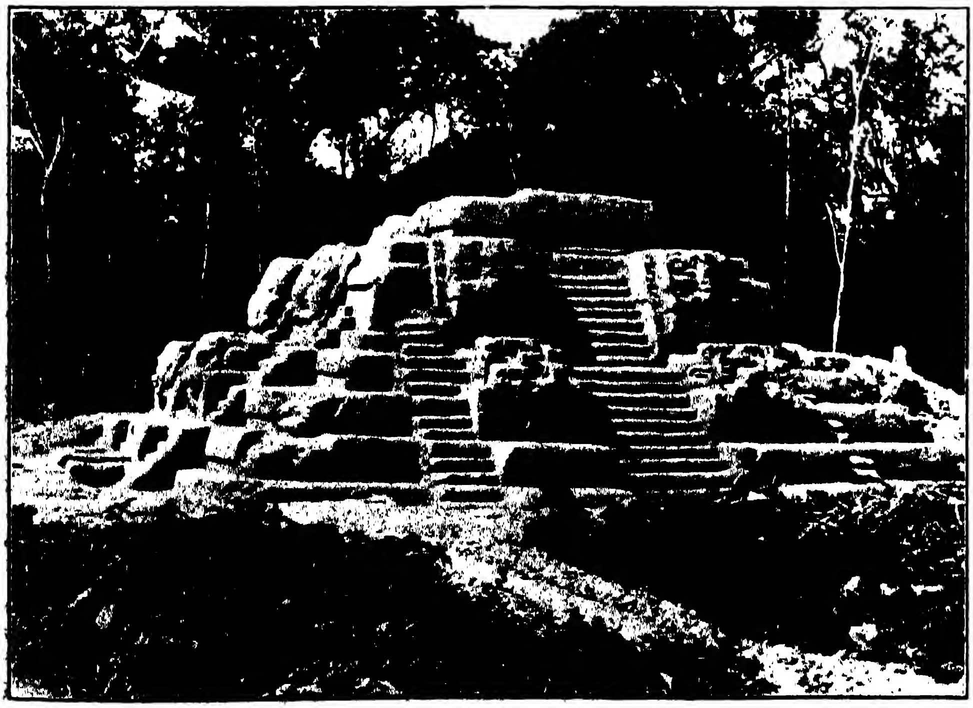
FRESH DISCOVERIES IN MAYA EXPLORATION

The results of the Maya exploration work of the Carnegie Institution of Washington were described at the International Congress of Americanists in September. Dr. A. V. Kidder, Dr. S. G. Morley and other members of the archeological staff presented reports covering a season which has thrown fresh light upon that remarkable race of aborigines which the New World developed. Two events in particular stamp the 1928 working season as having been one of unusual richness—the excavation of Pyramid E-VII at Uaxactun (Wah-shawk-toon), Guatemala, and the discovery of an ancient ceremonial treasure in the Temple of Warriors at Chichen Itzá, Yucatan.

Some two thousand years ago the inhabitants of a distant city in what is now the northernmost department of the Republic of Guatemala built a wonderful pyramid.

This pyramid, 85 feet square at the base and 25 feet high, was ascended by four stairways, one on each side. Colossal masks of fine lime stucco, the upper pairs fashioned in the likeness of grotesque human heads, the lower pairs after the manner of serpents' heads, flank these stairways and, like grim sentinels, guard the approaches to the holy region above.

Time passed. Probably very near the beginning of the Christian era this beautiful pyramid, built of uncut stone,



ANCIENT MAYA TEMPLE

AT UAXACTUN (WAH-SHAWK-TOON), GUATEMALA, UNCOVERED BY THE CARNEGIE INSTITUTION OF WASHINGTON. THE SUMMIT IS REACHED BY FOUR STAIRWAYS, EACH FLANKED BY COLOSSAL MASKS OF FINE LIME STUCCO, THE UPPER PAIRS REPRESENTING GROTESQUE HUMAN HEADS, THE LOWER PAIRS FASHIONED AFTER THE MANNER OF SERPENTS' HEADS.

and faced with dazzling white stucco was covered up, completely buried by the ancient inhabitants of the city. They built around it and over it a covering of rough rubble which, while it completely concealed the original pyramid, doubled the height of the new pyramid and also increased the area it covered.

Time and the growth of forest trees had almost completely destroyed its exterior finish, but enough remained to show that it had been a very steep structure some 50 feet high. Evidence is at hand to indicate that the new pyramid was used as the point of observation in a gigantic sun dial by means of which the positions of the equinoxes and solstices were determined for priests and people. Why the older and probably more beautiful pyramid was covered up and completely hidden, however, still remains an archeological mystery.

The original pyramid is perhaps one of the most beautiful examples of ancient American architecture that has come down to us. Its harmonious proportions, its pleasing silhouette, its dignified bearing, its dazzling silvery white finish, make it one of the most satisfying pictures of the past to be found anywhere in the world.

The top of the earlier pyramid is covered with a floor of hard white plaster painted a deep red. As this shows no traces of walls, or of any superstructure, one is forced to the conclusion that no building had ever surmounted it. It would seem to have been a place of sacrifice, a holy place in a very real sense.

In the coarse rubble forming the hearting of the apex three cysts were found, one of which was a grave of large, cut, untrimmed stones and mud. The grave contained the headless skeleton of a female, whose age was estimated at twenty-five, which lay fully extended, face down, the feet towards the west. Another cyst contained six pots, three of which were of plain red ware with flaring rims and three of plain brown ware with covers. The vessels were protected from the weight of the superimposed earth by large stones. The third cyst also contained pottery in which various articles were found, such as seeds, shells, dried gummy materials, pieces of obsidian, and an obsidian lancet, extremely sharp and well-made.

Three hieroglyphic stone monuments in the plaza of the ancient city were found to have been erected at the same time, and two of these have the very early Maya date 8.16.0.0.0, corresponding to 97 A. D., inscribed upon them. How much older than this date the earlier stucco pyramid may be, it is impossible to say. It would seem reasonable to suppose that at the time it was covered up it had been in use a century or more. If 97 A. D. marks the date when the older temple was covered, as is probable, then 2,000 years is not far from the real age of the original structure.

Having been in good repair when it was entombed by the erection of the secondary pyramid, and having been protected by the latter through the centuries, the primary pyramid, judged as a whole, may be said to be in practically the condition it was in when it was buried 2,000 years ago.

We wish to acknowledge our obligations to The American Geographical Society for the loan of the map of the Arctic Basin from "Problems of Polar Research," which appeared in the September number of The Scientific Monthly, and for the cuts from Professor Davis' book entitled "The Coral Reef Problem," which accompanied his article in the number for October. We regret that the credit line was accidentally omitted when these illustrations were printed.

THE SCIENTIFIC MONTHLY

DECEMBER, 1928

VISUAL ILLUSIONS OF MOTION

By Professor WALTER R. MILES
STANFORD UNIVERSITY

I. The Bystander's Illusions of Motion

We were standing on the lawn in front of the Stanford Quad when my friend said, "Did you notice that sprinkler a minute ago? It was turning toward the right but it stopped and then started turning in the opposite direction. Some of them are made that way. I suppose the inventor thought that his device would throw the water on both sides of the plants." This illusion of motion, seeming to turn first one way and then the other, well known to the psychologist, is more often called the "windmill illusion" for the simple reason that windmills are older than lawn sprinklers and that their twirling blades are frequently observed from the distance most suitable for the appearance of the illusion. Sellers of windmills know about this oddity of perceived motion. Not infrequently it causes them prolonged discussions with some irate customer who stoutly contends that there is a defect in the mill because it revolves now in one direction and again in the opposite one. Windmills, electric fans and lawn sprinklers with revolving arms are alike in resembling a wheel with prominent spokes and an insignificant rim. They are quite open and when viewed nearly edgewise and at some distance it is difficult to tell positively which parts are in the foreground and which in the background. If foreground is actually seen as foreground the motion will be in one direction, but if background is for the time seen as foreground the apparent motion will be in the opposite direction. The illusion, therefore, belongs to the "reversible perspective" class, being a case of confusing front with back as illustrated by the diagram (Fig. 1). If

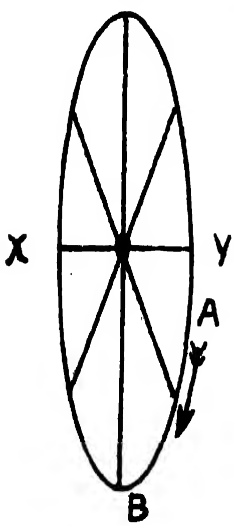


Fig. 1. If Y and the arrow appear to be at the front of the figure then this section is moving downward, but if X is seen as foreground then the front is moving upward. The figure may also be seen as without perspective. Similarly a lawn sprinkler may at times be seen to expand and contract rather than to revolve.

at first glance this wheel appears to be facing toward the reader's left hand then the foreground is represented as moving downward, but if the wheel is facing the right then the foreground is moving upward. The wheel may of course be seen by the same person in either of these two ways. The shift can to some extent be controlled by fixing the eyes first on one part and then on another (x and then y). This is an illusion of motion, but is one that occurs independently of the observer's position: he may be stationary or moving, whether by his own locomotion or carried by some vehicle.

Seeing Movement in the Motionless

The familiar circumstances just considered were those where an *actual motion was reversed*, that is, it was misinterpreted as to direction. Because we have a clear impression that motion is or has to be one way or the other this has been called an illusion of motion. There are of course many instances where the amount or rate of motion are not rightly perceived, but here since there is no natural dichotomy, it is common to speak of "errors of judgment," some of which may be overcome by training and experience.

Now we come to another accepted illusion in the class of natural events of which the waterfall is an example. When an observer, in this case preferably stationary, steadily watches the moving column of water he has presently a definite impression that the adjoining banks of rock and earth and the projecting boulders and tree trunks forming islands within the fall are all moving in a direction opposite to that of the water. Here he does not misinterpret the direction of the actual motion that exists but rather *creates an opposed motion* for the stationary areas that border or are inclosed in the field of real motion. This illusion is present and sometimes awkwardly so when we try to cross a stream on a foot log. We get the same effect when slowly moving reading material appears on a motion-picture screen, and in the apparent motion given to the moon and to objects on the horizon when clouds are moving rapidly across the sky. This illusion is not conspicuous as we view a moving train on a distant landscape, but if we are standing near the edge of a platform as a long train passes we should exercise care: a motion illusion of great hazard may confuse us, one that has doubtless been the real reason for many a person's falling under the train.

The "waterfall illusion" evidently depends on the objective condition of movement of relatively large areas of the visual field. This type of visual experience does not depend upon confusion between foreground and background. It rests rather on the tendency for the visual field to operate as a compensating system balancing its parts one with reference to the other. This tendency for the visual field to behave as a realm of compensating motions, some real, others induced, is especially noteworthy when the observer is being carried along in a train, automobile or airplane. We will presently return to a consideration of it under these conditions.

The Puzzling After-Effect of Movement

One point more on the waterfall illusion concerns the after-image of movement as it relates to industrial operations. Advertisers now and again for window attraction make use of a disc on which a black spiral is traced, the disc being made to revolve slowly. If a person looks steadily at the center for a few moments and then glances at some stationary object he sees a curious swelling or shrinking (according to which way the spiral has been revolving) in whatever is looked at. The impression is inescapable; it is the after-image or after-effect of the movement. If a mechanic

has in his field of view and is watching continuously and closely a rather slowly moving area, rotary or linear, which he is adjusting to some other surface or point, on stopping the motion of approximation he will have the distinct impression that the thing is backing away or that the motion is reversed; he must beware of trying to compensate for this at the moment. This is not a defect of the machine or an eye trouble. It is a normal phenomenon of vision. If it is bothersome it can be reduced by arresting the motion before the final contact is made, thus allowing the after-effect to die away.

The Dark Spook and His Speed

The "picket-fence illusion" represents a third group of visual experiences in which apparent *speed of movement is accentuated.* It is not dependent on peculiarities of the eye but is normal and objective. On looking through one picket fence at another farther away one sees alternate "dark" and "open" spaces themselves much wider than the individual pickets or openings in the fences. According to the distance that the fences are apart and the position of the observer these dark phantoms are broad or narrow. The same phenomenon may be produced by window screen and lace curtain. It is directly made use of in a visual acuity test object manufactured by Bausch and Lomb. In this case ruled glass gratings, the scratches filled with opaque material, are superimposed. One plate is rotated on the other about an axis perpendicular to their surfaces and dark bands appear. See Figure 2. The width of these is determined by the degree of rotation. The phantom is stationary if the screens and the observer keep constant position with reference to each other. A slight movement of either screen or observer produces a large and unexpectedly rapid movement of the phantom.

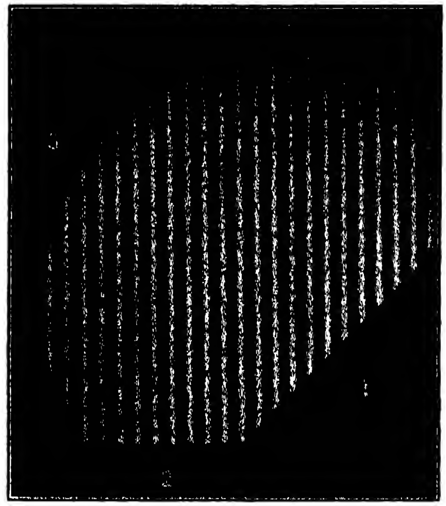


FIG. 2. DARK BANDS MADE BY SUPERIMPOSING TWO GLASS GRATINGS RULED 200 LINES TO THE INCH. THE SCRATCHES ARE FILLED WITH OPAQUE. ROTATION OF ONE GRATING ON THE OTHER MAKES THE BANDS WHICH APPEAR IN THE ILLUSTRATION. THE EFFECT AT THE INTERSECTION OF THESE BANDS WITH THE BORDER DIFFERS ACCORDING TO THE ANGLE AS SHOWN AT THE POINTS NUMBERED ON THE ILLUSTRATION. A SIMILAR EFFECT OF BANDS COMES FROM LOOKING THROUGH TWO PICKET FENCES OR TWO SCREENS.

The Movies Just Appear to Move

Finally, for the stationary observer we may mention the "firelight illusion" of motion. Sitting near an open fire that is flickering rather than vigorously blazing one notices that the andirons, crane or other objects appear to execute rapid shifts in position changes sometimes lateral and sometimes vertical. This is due to the fact that the objects are illuminated from one position and then another as the fire blazes up, now here and now there. The highlights and shadows change for the objects and for the general background. In place of seeing the object first this way then that way a kind of fusion takes place in vision which bridges the gap and the object seems actually to move from one position to another, back and forth. One

of my colleagues, a physicist, once called my attention to an experimental set-up which included wiring between lamps well spaced, that illuminated alternately. Under these conditions some of the wiring not in immediate contact with the baseboard seemed to move forward and backward as does a conductor in a strong electrical field. To convince one's self that the wires were not moving one needed to actually touch them while the lights changed. In this situation *we create what appears as primary motion* in really static objects by giving successive views a meaning of motion. Ordinarily an object which occupies first one position and then another has to move across the distance that separates the two points. This is in general so fundamental that it tends to become the basis for all our interpretations. The principle plays a prominent part in the effectiveness of electric flash signs, it is basal in motion pictures and probably at root is related to the condition that our vision is not really continuous. The "firelight illusion" is as old as the name I have given it implies, but recent psychological discussion has made much of it under the term "phi-phenomenon" and it is prominent in the new Gestalt psychology.

II. The Train Traveler's Illusions of Motion

Under the conditions present when I am being rapidly moved by train, automobile or airplane nearly everything which makes up my visual field is a moving image. The situation is just the opposite when I stand leaning against the fence looking into the Grand Canyon. Sitting on the observation platform while the train moves along at forty-five miles an hour the visual field has to be constructed in a totally different manner, and to describe it in most general terms, everything is turned into the "waterfall effect." The railroad ties and the crushed rock of the road bed, the cinders and the grass on either side of the road make up a softly merging band of gray, brown and perhaps green. If I fix my eyes about a hundred feet down the track I see nothing near at hand in detail except the clear-cut steel rails which appear to flow rapidly into closer approximation with each other. The clouds and sky in the upper part of my visual field in place of flowing from me

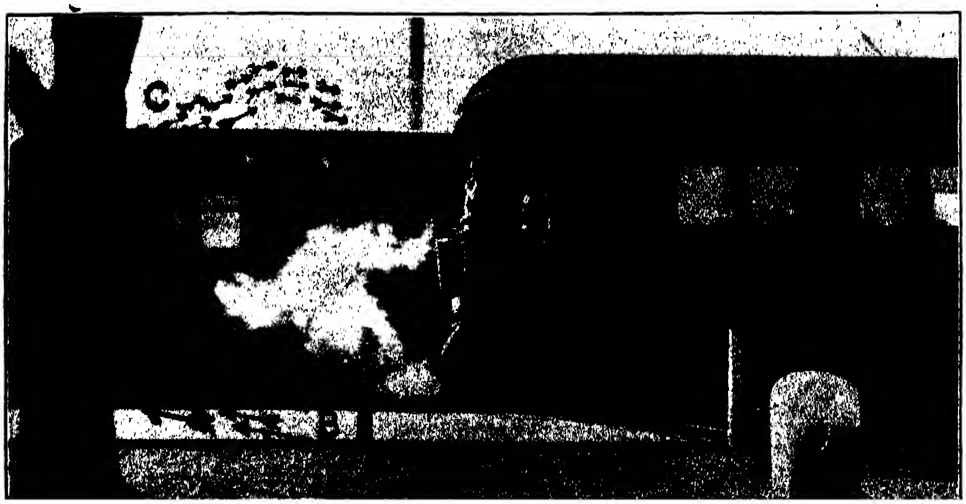


FIG. 3. ILLUSION OF MOTION WHEN RIDING ON THE OBSERVATION PLATFORM. A, DIRECTION OF THE TRAIN'S MOTION; B, MOTION IN THE LOWER PART OF THE VISUAL FIELD; C, ILLUSION OF MOTION IN THE UPPER PORTION OF THE FIELD OF VIEW.

appear to rise rapidly above the horizon as if a storm were approaching and were gaining on the train. See Figure 3. This is our old "waterfall illusion" in a new form. As I am being rapidly moved forward, the immediate territory serves as a fixation field, and as it sweeps rapidly away the opposite motion is induced in that part of the visual field that is going away from me relatively more slowly. We have already mentioned the compensating features of the visual field. White objects in the field of view cause other portions of the field to appear darker. Prominent colored objects or patches of color cause shadow fields of the complementary color to be induced in adjoining areas. Portions of the field seen in clear detail appear to be nearer to us than vague or dim portions. The vague parts seem, in fact, to recede, thus emphasizing a depth factor which, in general, applies to the whole visual field and differentiates foreground and background. The lower part of the visual field is interpreted in general as near at hand and in contrast to this the upper part receives the interpretation of distance. Now we see again evidence that the visual field operates as a compensating system maintaining an equilibrium in terms of its own content, for as noted above the introduction of large predominating areas of motion within the visual field induces the appearance of opposite motion in the adjoining large areas. Just as the induced contrasting color appears to be unsaturated, diffused and without sharp boundaries or strong body so the induced motion is in general less conspicuous than the moving areas which induce it.

If the sky is cloudless and without discernable details the traveler may scarcely be aware of the induced movement in the upper part of his visual field. Yet the illusion may show itself in the apparent bending over of a tall tree or flagpole in such an environment

FIG. 4. THE TALL TREE, THE TELEGRAPH POLES AND THE FLAG POLE IN THE DISTANCE ARE APPARENTLY SWAYED FORWARD BY THE ILLUSION OF MOTION INDUCED FROM THE RAPIDLY RECEDING FOREGROUND.

as that shown in Figure 4. However, if the train stops and the moving stimulus is suddenly withdrawn there is a prominent after-effect of motion, which is similar to what he would experience if he found himself suddenly transported to the front end of the same train in motion. The platform and road-bed seem to be rushing toward him. This is, of course, the ordinary experience when riding in an automobile, where the objects approached are faced rather than receded from. If under these circumstances one looks steadfastly a long distance down the road and at the same time pays attention to the objects near at hand which are being immediately approached, the latter appear to swell rap-

idly in size. The sky and clouds recede as if driven by a rapid wind in the direction of one's travel, the distant mountains seem to sink down and in general the landscape appears somewhat flattened. Whether the landscape is receding and the upper portion seems to come forward or is being approached when the upper part seems to recede, that is, whether the traveler is facing backward or forward there is an axis about which the two halves of the visual field appear to revolve. This axis is not very definite. I can easily make it the far horizon if I fixate that locality, or if I fixate a position considerably nearer, it seems in general to be there, but I can not under any circumstances bring it nearer than several hundred feet from the train.

The Illusion of Shrinking and Sinking

As my journey proceeds objects are rushing into my visual field from both sides. When they come in they are large, but owing to the rapidity of my motion in a short time they have astonishingly decreased in size. The train passes over a bridge with steel superstructures. As we leave it (see Fig. 5) the structure looks large and occupies a considerable portion of my visual field. Less than sixty seconds later (see Fig. 4) the same bridge appears only faintly at the point where the tracks seem to converge, having shrunk to less than one one-thousandth of the previous visual area. As the bridge recedes during these few seconds it has seemed actually to sink into the ground or to shrink like a punctured balloon.

Watching the telegraph poles as they rush in and recede, we try to account for their rapidly changing size: they seem to sink into the ground or to telescope on themselves. If linemen are working on the poles so rapidly passed one can not be sure whether a given man is holding his position steadily or climbing down or up the pole. Observing men adjusting the lights on the derail switches I have noticed that one frequently gets the impression that the man is climbing down from the light whereas this effect is simply the result of the rapidly decreasing size of the whole field of vision, in other words the lowering or shrinking of the object in question.

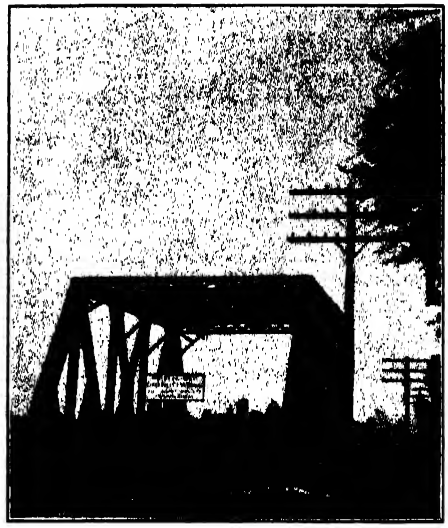


FIG. 5. A BRIDGE JUST PASSED OCCUPIES A LARGE PORTION OF THE FIELD OF VIEW AND ONE MINUTE LATER, AS IN FIGURE 4, IS REDUCED TO 1/1000 OF THE FORMER APPARENT AREA.

The Illusion of Twisting and Revolving

A third and very striking illusion which is to be noted from the observation platform is "twisting." Here the telegraph poles serve us best as objects of demonstration. When we pass the poles the cross beams to which the wires are attached are at right angles to the rails. At the instant of passing we can see only the ends of the cross beams, but about five seconds later we are looking at their sides (see Fig. 6), that is, the telegraph pole has taken on the aspect of a cross. The change in point of view is

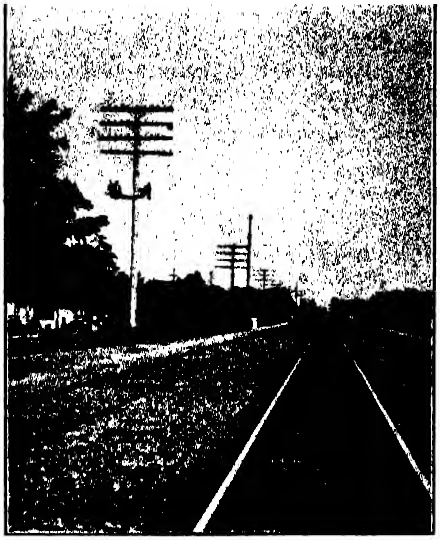


FIG. 6. THE ILLUSION OF TWISTING MAY BE SEEN EASILY FROM INTENTLY WATCHING TELEGRAPH POLES AS WE ARE SWEPT RAPIDLY PAST THEM.

so rapid that if one fixates the pole, trying to keep his eyes definitely on it as it "travels past," one has the impression that it twists in the ground, executing about an 80° turn. Here the motion is imputed to the object itself to account for the change in point of view, and therefore one gets the impression that the pole revolves on its own axis at first very rapidly and then in a negatively accelerated fashion. The poles at one's right revolve clockwise, those at the left counter-clockwise, in each case appearing to execute almost a quarter turn.

This revolving of objects is always a conspicuous illusion of the visual field as one sits in the coach, looking out from the side of the train. A house standing near the track if observed in this manner seems indeed to turn through an angle greater than ninety degrees. As one faces the window and turns his eyes far to one side so as to pick up the image of the house when it comes in view and then follows it with a pursuit movement of the eyes until it goes out of view he gets this revolving illusion most distinctly. The same illusion is conspicuous with reference to a fence that runs off at right angles to the railroad track. If one fixates a point on the fence say three hundred feet from the track, before passing the end of the fence, the entire line of posts and rails will seem to revolve as around an axis located at the point of visual fixation.

The "Waterfall Illusion" Seen Sidewise

We thus see that the revolving illusion is closely associated with the general illusion present in the field of view as noted from the side of the train. In place of having the motion in the direction to and from the observer in the direction of travel it is now lateral to him. The lower part of the visual field rushes backward as he faces forward, while the upper part of the field is in general apparently moving forward in the same direction as the train. Observing the clouds one has the impression that the wind is blowing them in the direction that the train is traveling. The imputed motion is not limited to the sky and clouds but tends to include all of the landscape beyond the actual point of visual fixation. It is an approximate law of vision that an object which is seen clearly and constantly appears at rest, as compared to the remainder of the field. This statement is easily confirmed by the experience of passing through a wooded region. If as I pass, whether walking or riding, I fixate a tree a hundred feet away at the side, all the trees nearer will appear to pass me in one direction while all those farther than the fixated tree pass in the other direction. If I walk through the woods under a bright moon the moon will seem to be going in the same direction as I. There is nothing beyond the moon that I can fixate and I can not therefore get the moon included on the near side of

the axis about which my visual field seems to divide or revolve.

On Riding Backwards and Forwards

In place of looking out of the window suppose I sit at the read-end of the coach and look steadfastly at the front end, giving attention, however, to the peripheral field with the movements rushing by on both sides outside the car windows. Presently I become aware that the front end of the coach seems to be retreating, the coach appearing to grow longer. This is a compensation in the central part of my visual field for what is happening of the opposite tendency on the sides. This does not annoy me because the lengthening of the coach or tho receding of the front of the coach from me is taking place in the direction that I think myself to be traveling. If I now change my position to one at the front end of the coach and, facing backwards, fixate on the rear end I see the landscape on either side rushing back and away from me as it does when I am on the observation platform. The end of the coach and all that makes up the lower, central and upper portion of my visual field has induced in it the opposite tendency, that is, it seems to be coming toward me. Probably this is one of the chief reasons for the discomfort that many people experience in riding backwards. Nervous people may get the impression that the car is crowding in on them.

Reading on the Train

We do not like to read with an unshaded lamp quite close at hand, because of the distracting streaks in the field of vision as the eye goes through its series of glances and pauses across the page. The visual field outside the limits of the book page or paper tends to claim our attention and if it contains an object of striking contrast such as the bright globe of the lamp, reading is made more difficult and more fatiguing. Similarly the train traveler should avoid holding his reading material in such a way that any considerable portion of the visual field is played upon by the moving landscape. If the visual field has much movement occurring across it, then that portion occupied by the book or paper will give the impression of movement in the opposite direction. This impression must be contended against and in a way compensated for by visual fixation and eye movements and therefore constitutes a definite handicap and a fatigue hazard. The visual field should so far as possible be limited to objects that are traveling with the reader. The common extended newspaper, tending as it does to take up nearly the whole visual field, has natural advantages for train reading.

Which Train has Started?

When our train is standing in the station with a train on each side we are often confused at the moment of starting, not knowing certainly whether they or we are pulling out. Ordinarily I impute the motion to myself and think that my train has started very slowly and without jerks. In this illusion of self-motion I follow what seems to be a deep-grained human habit, perhaps a fundamental one, for ordinarily in most familiar situations I am the object that moves with reference to a generally stationary landscape. Therefore, when nearly the whole visual field moves silently and evenly to one side it is very like the experiences when I move my head or when I walk, and thus I can quite easily convince myself that I am in motion. This is particularly true if the rate is within my walking or perhaps running speed. Then I seem as a rule to be the mover unless I find my experience wholly lacking in those cues

of auditory and tactual nature which would refer to the jostle of the train and to its rumble. If these are entirely absent I may suddenly correct myself. This mental measure which I have with reference to movement produced by my own locomotion pertains to the clearness with which I see things as I pass them. It plays a deciding rôle in causing the impression of *"myself moving past"* or at other times with higher speeds of *"having the landscape move past me."* These impressions may be designated as the *pedestrian or slow vehicle experience* as against the *panorama experience.*

When a freight train is traveling slowly side by side with my passenger train and in the same direction, I look at the freight and feel we are traveling indeed very slowly. I appreciate only a relative difference in speed between the two trains whereas when I look at an open landscape on the other side of the coach I instantly adjust myself to the impression of rapid travel. The sense of movement is thus nothing trustworthy in itself except as it is based on trustworthy visual or tactual experience. No resident on the earth has the clear direct impression of rapid transit through space. The aviator if he sticks his head down in the cockpit has little more sense of traveling through space, in fact he has rather less, than a child seated on a rocking horse.

The Illusion of Sharp Vision During Motion

When we are in rapid transit we see best those things which are in line with our direction of travel. Thus from the side of the car we see "clearly" telegraph wires, fences and roads paralleling the track. The road is a particularly interesting thing to watch as I hold my visual position with reference to the frame of the window. The light cement road looks like a soft feathery path with two light-brown bands running through it (oil drippings from the two lines of traffic). The black streak of asphalt which divides the road in the middle appears indeed very black and sharp, but the equally black asphalt bands with which cracks in the cement have been patched or different sections of the road have been joined fade out entirely. I see these cross marks only if I jerk my eyes back and forth. I look at the telegraph wires: they seem to glide through my visual grasp almost as if between my fingers. They rise and fall slowly and evenly as the swell of waves. There is a moment of flutter when the telegraph pole goes by and a little unevenness when the splices "go through," but otherwise I have the impression of seeing the lines with great clearness and detail which I know to be entirely an illusion.

Two Visual Devils

During train travel many of the objects remain in view for a long enough time to satisfy the observer. However, there are some momentary visual experiences that may be cited. One annoying thing in all train travel arises from the fact that it is difficult to see the name of the town on the railroad station. The station for obvious reasons is near the track, and if your portion of the train stops far from the station or the train passes through without stopping observers from the side of the coach may fail to make out the name. There would seem to be a good opportunity in most towns and cities for "town-name-ads" well placed about two hundred or three hundred feet from the track, one on either side, that may be read when going or coming. In the matter of town name and local information, auto travelers now have the advantage.

In contrast to this rather negative momentary visual experience there is a

positive one that is of a very troublesome nature, and it is not an illusion! This arises especially from tall trees planted at the side of the right-of-way, in such a position that they cast their shadows across the track. A row of such trees, beautiful as they may be, produces an exceedingly irritating and painful flicker for thousands of travelers who are trying to write or read when the train passes that spot. If such rows of trees could be planted far enough back from the right-of-way so that their shadows would not fall upon the passing train the effect on the landscape would be equally pleasing and all the non-blind passengers traveling over that line would be grateful—if they thought about it. Transportation companies surely owe it to their patrons to guard them against this tormenting devil.

Grabbing an Eyefull

When we pass a freight train on the siding or perhaps moving in the opposite direction we are at times annoyed because our field of view has thus been cut off. However, the persistent observer can grab almost an eyefull of fairly non-illusion material from the momentary glimpses which are available to him through the openings between cars. Freight cars are in general about forty feet long and the opening between them is approximately four feet, so that when we pass a freight train it is cutting off the field of view about nine tenths of the time. The duration of view or glimpse that we get lasts from one twenty-fifth to one fifth of a second according to the speed of the train. We know from a great deal of laboratory experience with exposure devices that if one is looking at the right place and is ready for the exposure a brief uncovering of the object really serves the purpose for quite a comprehensive view. In Figure 7 one sees through the gap an engineer standing by his cab, and the numbers on the cab are legible. For such glimpses much depends on how near we are to the open-

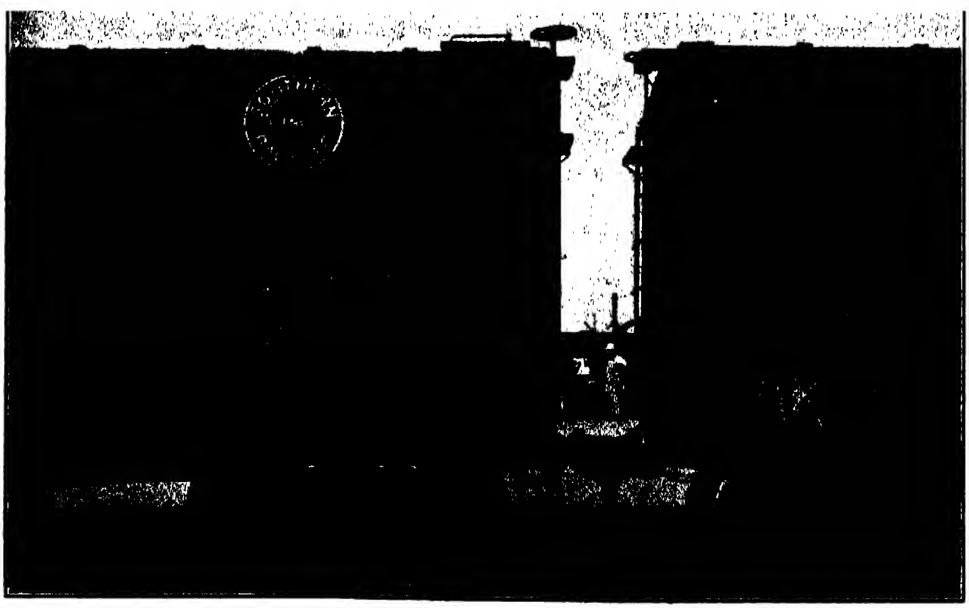


FIG. 7. THE FREIGHT CAR EXPOSURE DEVICE WHICH PERMITS US A GLIMPSE FOR ABOUT ONE TENTH SECOND. WE MAY SEE CONSIDERABLE IF ATTENTION IS RIGHT.

ing and what is to be seen. There is no point in just mildly giving up in the presence of a clumsy freight train. What we see is like a succession of lantern slides. This glimpsing of things through the big exposure device of a freight train tells us a very important story. In a nutshell it is that vision is quick and comprehensive and that in general we look for a longer time than is necessary. We can economize vision and save ourselves visual fatigue by looking for shorter periods and with greater attention.

Movement and Experience

Some form of travel by rapid transit is now a characteristic feature of man's life. He does not travel with his eyes shut. If he looks at the region through which he passes his retinal fields must in general be fields of motion. We find that this condition brings about definite visual distortions or illusions. These are so pronounced in some cases as to make it impossible for him to be certain in his judgment. They show that the make-up of the visual field at any moment results from relative visual impressions or relations between these impressions. A visual field is a compensating system of experiences, one experience interpreting the other. What at one moment seems in motion may at another moment seem at rest. If a large part of the visual field actually moves in one direction other parts of it will appear to move in the opposite direction. In this complex known as visual experience we have a picture representing the whole range of dependent relationships which constitute man's environment and the very texture of his existence. Up and down, north and south, dark and light, movement and stationariness, all of these things have to be taken in pairs. There apparently are no fixed and independent points belonging in these systems, and to imagine that such stationary parts exist is simply to be caught in what is the greatest illusion of the time-space-being picture.

GEOGRAPHY OF A PORTION OF THE SAN LUIS VALLEY

By Professor RALPH H. BROWN

UNIVERSITY OF COLORADO

THE cultural landscape of the Monte Vista region, in common with that of all the irrigated portions of the western part of the San Luis Valley of Colorado, has resulted from the shaping of a rural life essentially middle western in its salient features to fit the stubborn demands of a remote, high-altitude, arid, intermontane valley to which, at a time seemingly longer ago than it really is, a Spanish-Mexican life had been incompletely adjusted.

DESCRIPTION

A Modified Middle Western Cultural Landscape

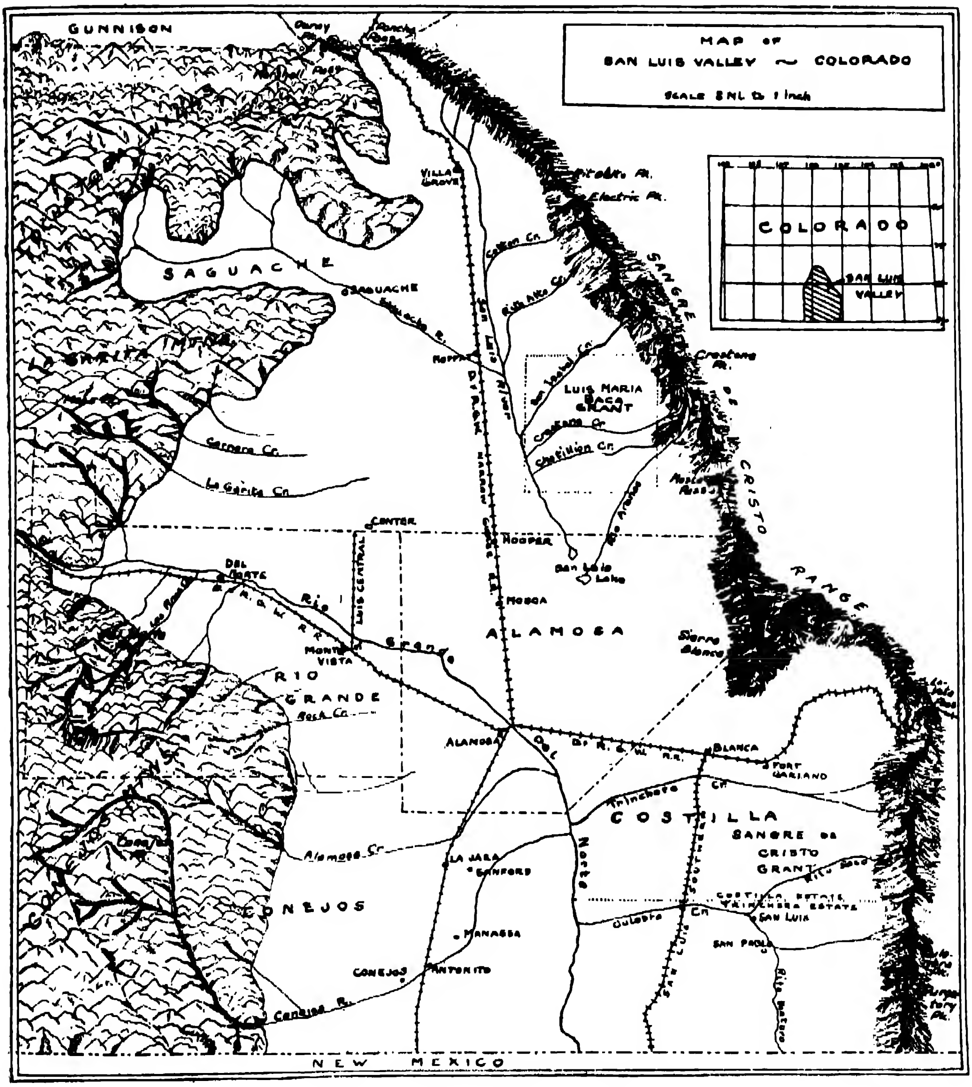
In the rural districts of the Monte Vista region, the homes are spaced at about one-half-mile intervals along the straight section-line roads which criss-cross without natural hindrance the monotonous surface of the compound alluvial fan of the Rio Grande del Norte. These homes and their surrounding barns and sheds—minus windmills and silos—possess not only the atmosphere of practical efficiency, but also the actual conveniences and luxuries, of their corn-belt prototypes.

A further modification of the local architecture and one suggesting also the delicate way in which an autochthonic culture has been fashioned to meet the practical needs of a more advanced society, is the ubiquitous potato cellar. Constructed in the main of thick walls made of local adobe dried in the sun, and covered with sod roofs, they are strongly reminiscent of the picturesque Mexican house. Moreover, the three-foot-thick walls are found to be a careful adjustment to the absolute minimum winter temperature of -30 degrees F., in the adequate protection provided to stored potatoes, the great cash crop of this locality.

The Mexican adobe dwellings of the indigenous culture are now to be found only occasionally in the rural districts and practically never in the highly prosperous parts thereof. Commonly these older one-story houses are clustered about the outskirts of towns and villages as, for example, in the Lariat section of the town of Monte Vista. The latter, of three thousand population, quite typical of the communities spaced at about twenty-mile intervals across the

(Photo by Eben Fine, Boulder)

A VIEW OF CHAMA IN THE EASTERN PART OF THE SAN LUIS VALLEY.



broad, flat floor of the central section of the valley, is given over to trading in the produce, entirely agricultural, of the surrounding irrigated country, of necessity seeking a market in regions of denser population. Almost replicas of small towns in the middle west except for the Artesian wells and the gurgling irrigation ditches which thread the streets, they seem curiously misfit in the spectacular natural setting provided by the foothills of the San Juans only a dozen miles to the west, and about forty miles to the east by the inspiring majesty of the Sangre de Cristo Range, which culminates in the massif called Sierra Blanca.

Evidences of Recent Change

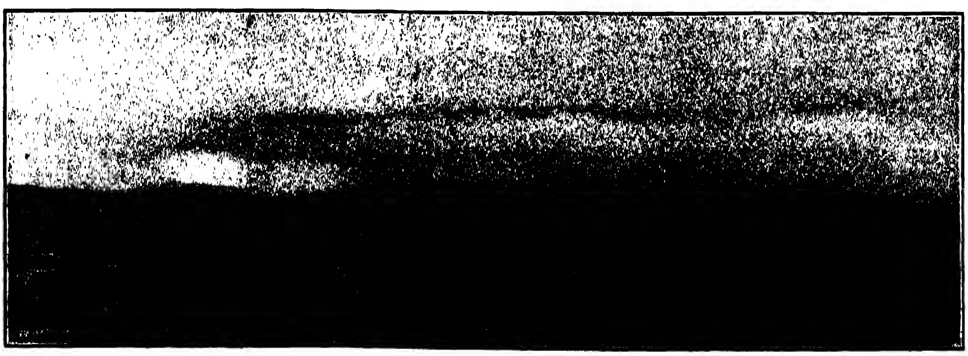
Evidences of successive stages in the settlement of the valley are also unmistakably recorded in the landscape. The older farmhouses, bearing many evidences of pioneer days, are notably close

(*Photo by Eben Fine, Boulder*)

THE ADOBE HOUSE IS STILL TO BE SEEN IN PARTS OF THE MONTE VISTA REGION.

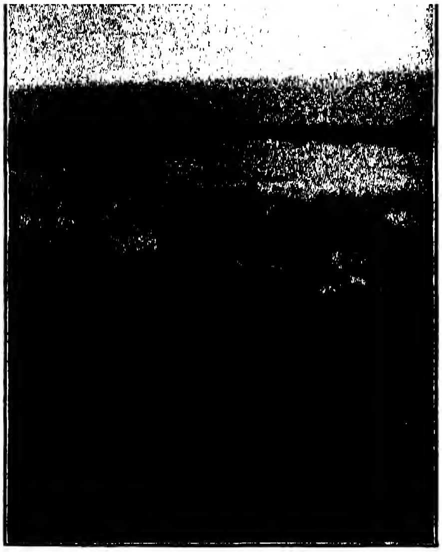
to the Rio Grande or to the smaller streams which debouch from the mountains upon the plain and are lost in it as they flow across the sandy surface. The newer and more modern homes, on the other hand, are obviously concentrated in the higher parts of the fan, across which great open trenches carry water to points twenty-five to thirty miles north and south of the Rio Grande. These main ditches, like the roads, stretch for miles without a turn, and from them water is deployed in minor canals throughout their lengths.

Indicative of changes of quite another sort is the increasing frequency with which abandoned farms, vacated land and long-unused irrigation ditches are met with as one goes eastward down the slope of the fan. Not a few vacant houses, especially about eight miles east of Monte Vista, were at one time apparently substantial homes. That profound changes must have taken place within a generation is also made known by the institution of recent drainage districts in the localities of widespread farm abandonment. The nearly stag-



(*Photo by Chas. F. Snow, Boulder*)

THE NATURAL LANDSCAPE, LOOKING EAST TO THE SANGRE DE CRISTOS. SUMMER STORMS ARE FREQUENT IN THE MOUNTAINS.



A SEEP ZONE IN THE LOWER FAN.

nant water of feeders to open ditches which return the water to the Rio Grande lies on either side of almost every road of importance. Large tracts are artificially drained by covered drains constructed of wood, found to be the most practical material for this purpose here. Locally in all parts of the Monte Vista region, the occurrence of alkali and moist land attests to the closeness of the water table to the surface and the frequent intersecting of the two. Such areas are locally called "seepy land."

The Natural Landscape

Strikingly different are the cultural and natural landscapes of the Monte Vista region—a continual reminder of the great significance of irrigation to this region. The generally monotonous, light sandy surface of the natural landscape is made locally rough by low sand dunes ineffectually held by tufts of grass and bunches of woody bushes. This rough surface bears ample testimony to the strength of the winds which sweep down over it from the mountains, and to the scantiness of the yearly rainfall which, in actual figures, is less than eight inches. Looking westward toward the San Juans the fan slope rises imperceptibly at first to the rolling, gravelly upper slopes which are finally displaced by the steep, parched foothills. Desolation is the keynote of this picture—a barrenness made the more evident by the apparent productiveness and attractive verdure of the irrigated land.

Evidences from Land Uses

Notwithstanding the necessity for irrigation, the farm units here are quite comparable in size to those of the Middle West, the average holding in the Monte Vista region being slightly over three hundred acres. In the uses of the land one may again see the intricate manner in which the cultural landscape has been shaped to harmonize with the environment. Data support the general impression that this is largely a region of stock-raising. Indeed, of the 318 acres of an imaginary composite farm of the Monte Vista region, 48 per cent. would be in native pasture or native grass to be cut for hay, and 42 per cent. in cultivated crops ranging themselves in acreage as follows: peas, potatoes, alfalfa, barley, oats and wheat. Adding to the acreage of native grasses the cultivated crops which are also used for animal feed, it is found that fully 75 per cent. of the land in this locality is

BUILDINGS ON THE MEDANO RANCH, IN THE EASTERN PART OF THE VALLEY, SAID TO CONTROL 150,000 ACRES.

(*Photo by Eben Fine, Boulder*)

LOOKING EAST ACROSS THE VALLEY FLOOR TO SIERRA BLANCA.

used directly or indirectly in the animal industries. Especially striking in this connection are the large acreages of irrigated grass lands, dotted here and there with large haystacks.

Interpretation

Few Present-day Reminders of Original Culture

The Spanish-Mexican culture appears to be one of comparative antiquity—though it actually existed as late as 1850—because as a type it left few marks which permanently withstood the onrush of the more aggressive American pioneer, bringing with him the civilization of the Middle West. The San Luis Valley was, before the latter's arrival, a region of far-flung stock ranges, of widely spaced ranch houses, of Mexican plazas distant scores of miles from one another in parts of this intermontane valley as large as the state of Connecticut, which had been partially divided into great land grants.

This extension of Latin civilization northward into Colorado was fostered by the Mexican Government as a feeble display of power in a peripheral region. It was made possible by the irrigation of native grass lands with water easily taken from the smaller streams issuing from the mountains and crossing alluvial fans or cones at their bases. In certain remote portions of the valley the American modification of this culture, little changed from the original, still persists. Elsewhere, at least within the Monte Vista region, this earlier culture is observable only as a weak infusion in the present-day cultural landscape, adding to it bits of charm and picturesqueness, and little else.

By and Large a Wintering Place for Livestock

The characteristic which seems to penetrate all phases of the cultural landscape in both countryside and village is the organization of economy around the livestock industry. The chief activity of the region through two stages of culture

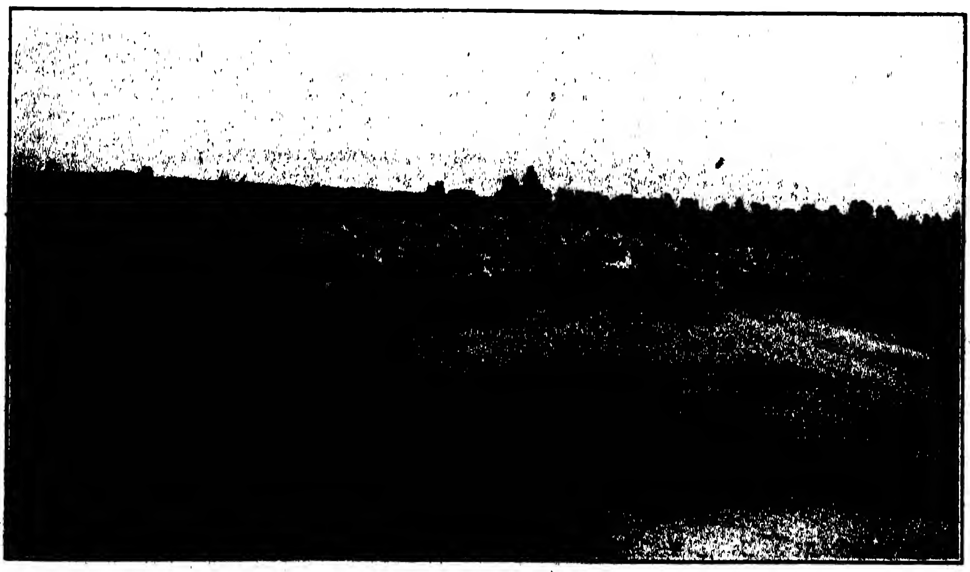
—and its only one during the first—it is indicative mainly of a restrictive rather than a positive environmental complex.

Primarily in this connection, the growing season is about 110 days, a reduction of the normal for this latitude resulting from the seven-thousand-foot altitude and basin conditions favoring air drainage. Certain uses of the land involving a higher net income are thus excluded; as, for example, the raising of corn and certain fruits. At the same time, native grasses grow well under irrigation, so much better indeed in regions underlain by the Rio Grande loam than other plants, that nearly all such land is devoted to this use. These broad expanses of open grass lands as, for example, in the Rock Creek District south of Monte Vista, are called vegas, whose dark green surfaces are in striking contrast to the barren land to which they are frequently in proximity.

However, large herds of cattle can not be maintained on farms whose size must conform to the high value accorded irrigated land. Thus it has become the common practice to drive cattle and sheep to the high mountain pastures of the San Juans for summer feeding, rights having been secured in the National Forest. In the meantime the owner is storing hay to be fed to the range cattle which are returned to the farm in the autumn. Sheep, on returning to the valley in October, are usually turned into the pea fields and finished for market in this way. The field pea provides fodder in this cornless region, while the method of harvesting the crop is indeed simple and easy. Other plants for winter feeding are also raised in this region of scant possibilities, which further suggests the centering of interests around the production of animals. Thus it is that the valley is still essentially a wintering place for livestock.

Land Uses of Past and Present Régimes

The present small acreage of spring wheat represents a survival from the time of first settlement of the valley, while



SHEEP RETURNING FROM THE MOUNTAINS.

THRESHING WHEAT NEAR MONTE VISTA.

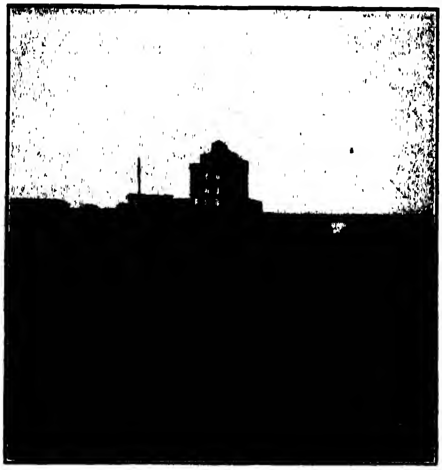
the potato is representative of the newer and more delicate adjustments to geonomic conditions.

Wheat, by sufferance of a permissive environment, fulfilled its place in the economy of pioneer days for which it has elsewhere become famous. Stories are prevalent of the crude methods employed here in seeding the wheat crop during early times—of casting the seed broadcast over soil prepared only by stripping it of growth with a steel rail dragged over it—and despite this of phenomenal yields resulting. Finally, diminished profits spelt the decline of this boom period of one crop. Although still the chief manufactural activity of Monte Vista is milling wheat, the mill at Hooper has closed its doors. The only other noteworthy manufactured product of Monte Vista is the "fresno," a kind of grading machine used in leveling land preparatory to its irrigation.

The potato, on the other hand, is in close adjustment to the relative coolness of the summer and the light sandy soils of this as yet pestless region. Production costs are held to a minimum by the widespread use of labor-saving devices for seeding and digging, machines whose use is made possible by the large size of the level fields and by the employment of Mexican labor in bagging the crop. One of the novel sights of the San Luis Valley during the autumn is the covered wagons being driven in from the south by Mexican families seeking contracts to bag the potato crop of some planter. Deprived of this migratory source of cheap and efficient labor, the valley would face a serious if not insuperable difficulty. That the potato is not a perfect adjustment to remoteness is shown by the periods of prosperity which are interspersed with years of distress arising from the equally certain surplus crop of other irrigated districts seeking the same markets.

Sub-irrigation—Causes and Results

The large size of the farm units, that is to say large for an irrigated region, is explained by the considerable acreages in native grass, by the predominance of the animal industries, and by the use, north of the Rio Grande, of a type of irrigation developed in this locality and called sub-irrigation, or, more simply and popularly, "subbing." It is a method of irrigation at once enforced by the dominant use of the land and by the shortage of labor in early times, and was made possible by the height of the water



THE CLOSED FLOUR MILL AT HOOPER.

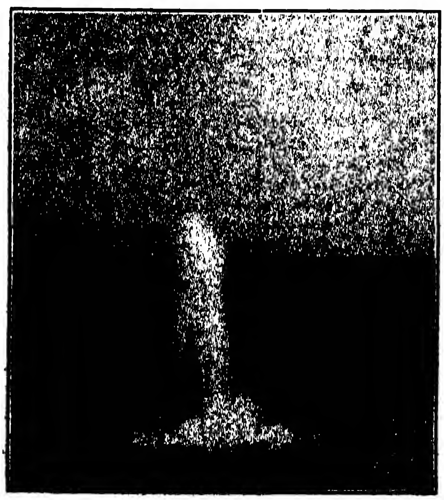
table and the abundance of water gathered from the San Juans by the Rio Grande.

In its practice, ditch water is used in large amounts to raise the water table and this, in turn, results in an excessive underground supply entering the drainage down the slope. Requiring less labor than the usual process of flooding, it lent itself well to the needs of a region dependent upon large acreages for its best success. Sub-surface water, with which the upper fan slopes are supplied, has found little use for irrigation in this region of abundant surface water, despite its Artesian characteristics. Small plots and gardens are, to be sure, frequently watered with it, after the water has been first warmed in the sun. Convenient also for watering livestock, it is popularly conceived to be an outstanding natural advantage of the region in that industry. Strictly, however, it must be accorded a secondary position in a geographic interpretation. Nevertheless, Artesian water is of the greatest significance as a source of domestic supply. Secured cheaply by sinking wells one hundred feet or so into the sands and gravels of the fan, it furnishes a constant supply for each home and renders superfluous artificial methods of raising water. Its constant low temperature, moreover, provides adequate refrigeration.

Excellent though sub-irrigation has been for irrigators on the higher parts of the fan, it has been ruinous to the majority of those farther east at a lower elevation. In "seep zones," that is at points of issuance of this excess water caused by the truncation of water-bearing strata, waterlogging of the soil and excessive alkali accumulations have resulted. This has led to the condition of abandonment described above. Organized effort has been brought into play in the drainage of these alkali lands in much the same fashion that fifty years ago cooperation was required for its irrigation.

Technique

The above study is the result of a chorographic investigation carried on in the vicinity of Monte Vista in the summer of 1927. So far as the author is



(Photo by Eben Fine, Boulder)

ARTESIAN WELLS ARE COMMON IN THIS PART OF THE VALLEY.

(Photo by Eben Fine, Boulder)

AN EIGHTY-ACRE POTATO FIELD NEAR MONTE VISTA.

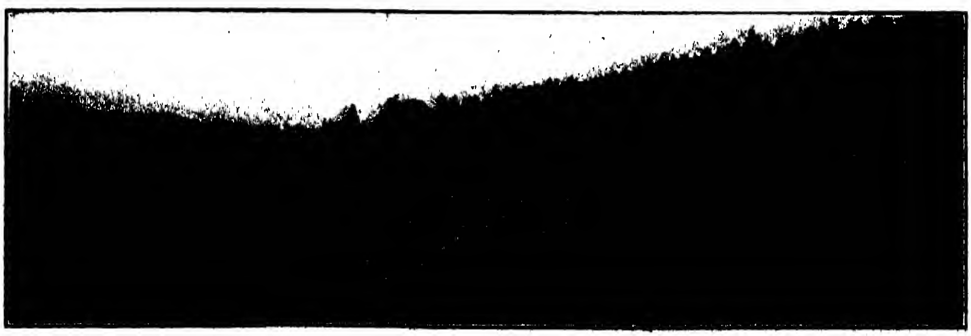
aware, this report represents the first attempt to describe and interpret the choroi of an irrigated region. Heretofore efforts in this newer phase of geographic work have been carried on in the humid east, largely because the leading investigators are located there.

The major elements of field technique, as outlined by such pioneers as Sauer, Jones, Finch, Colby, Whittlesey and McMurry, have been found to form a substantial framework for investigations in the arid west. Problems arising from the widely different conditions, however, make certain adaptations necessary.

In the first place, little aid was secured from study before entering the field, a condition which places an even greater emphasis and burden on field work in the west. Detailed historical information was not securable, while the soils and water supply studies made several years ago are now nearly worthless owing to the rapidity with which soil and drainage conditions change in arid regions through their improvement.

The first impulse of the geographer is to make the division between irrigated and non-irrigated land the leading item. This, however, is soon found to be not only impracticable, because land is watered or not for such a wide variety of reasons, but what is more important, such a procedure is not in accord with the spirit of geographic field work as distinct from economic surveys.

In the progress of the study it was found the better practice to place the major emphasis on recognizable geographic types as revealed by reconnaissance. This involves the mapping of environmental and cultural complexes on the same plat rather than the method recommended by Whittlesey. In the present study four types were clearly recognized and defined in terms of soil profile, natural vegetation, depth of



PONCHA PASS, NORTHERN ENTRANCE TO THE SAN LUIS VALLEY.

ground water, type of irrigation, presence of alkali and dominant use. Names given to the types are the Rio Grande Bottoms, the Vegas, the Seep Lands, and the High Lands, each one of these types being accorded a dominant color scheme. It is apparent that no type is pure throughout so that adherence to the simplified color scheme adopted facilitates the reading of the map. When the dominant color scheme of one type gives way to that of another, boundary lines between types may be drawn, thus simplifying one of the knottiest problems in geographic work.

This scheme would seem to be adaptable to most lands in which irrigation is a permanent institution.

THIS FARMSTEAD HAS SEEN BETTER DAYS.

TRANSPLANTATION OF ORGANS

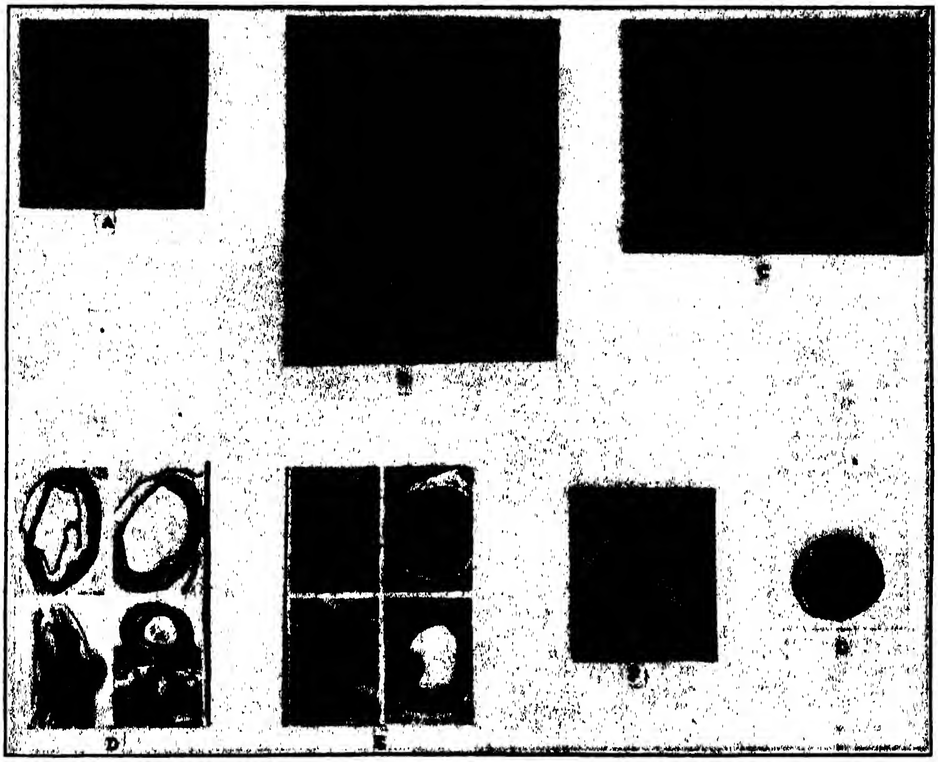
By Professor THEODORE KOPPÁNYI
SYRACUSE UNIVERSITY

TRANSPLANTATION, or grafting tissues and organs, is an ancient art, and even old East Indian physicians are reported to have achieved remarkable results with grafting portions of the skin. In our own advanced age the grafting of skin, periost, fatty tissues, etc., became standard medical procedures, mostly used to cover up bodily defects for cosmetic purposes.

But transplantation of intact organs is not as easily accomplished, for the taking of the graft depends upon its early vascularization, and unless this is accomplished, the graft degenerates rapidly and at its best becomes a foreign body incorporated in the host, without any function whatever. The graft thus must be saved from destruction through early blood supply, which, of course, must be established before the cells composing the organ are irreparably damaged. It is obvious that an early efficient vascularization of a large organ presents more difficulties than that of a thin layer of tissue. There are two other factors of equal importance which militate against the taking of the graft: the invasion of the grafted tissue or organ by the professional destroyers of the body, the wandering cells; and the defunctive regenerative power of the graft, for higher animals exhibit very little faculty to regenerate and regeneration is essential in establishing more intimate connections between graft and host. Fortunately, however, even higher mammals are able to *repair*, and wound-healing and some regenerative power of tissues within the organ suffice in many cases to secure the taking of a larger graft.

Many attempts have been made to ensure successful grafting of organs, but they have met mostly with only temporary success. A great technical innovation was introduced by Murphy and Carrel, who actually established immediate blood supply of the grafts by suturing the blood vessels of the graft to the blood vessels of the host. But even Carrel's results were not satisfactory and he soon lost interest in the problem, turning his attention to the question of tissue culture.

Although not essentially interested in methods and technique, I turned to the problem of organ transplantation because I needed this method in the hot pursuit of certain problems which troubled me a great deal. In 1920 I became fascinated with the perfect color adaptation to environment exhibited by certain species of fish and amphibia. If you place such an animal in a dark dish, its skin becomes dark; if you put it into a white one, it becomes light. This process is sometimes slow, sometimes astonishingly quick, according to the species. Now if you remove the eyes or cover them with black cloth, the animal ceases to show this nice adaptation to the color of the environment and assumes a uniformly dark, almost black color which is not responsive to external stimuli. The problems which confronted me were how and to what extent are the eyes concerned in this remarkable phenomenon. It was clear that the color of the environment was transmitted through the eyes, the question was whether this transmission is a purely chemical process, or whether it requires transmission through the optic



EXPLANATION OF FIGURES.

A. Frog with an eye transplanted on the site of the auditory organ. Operation performed by R. M. May at the Comparative Anatomical Laboratory of the Sorbonne. The graft established connections with the central nervous system. B. Goldfish with transplanted eye. The picture was taken thirteen and one-half months after the operation, which was performed by Professor Ask at Lund, Sweden. C. The picture shows the dark color of the blind fish and the lighter color of the fish with transplanted eye (Koppányi). D. & E. Histological demonstrations of regenerative processes in the transplanted eyes of Urodels. The experiments were performed by R. Matthey, of the University of Geneva (Switzerland). F. A mouse eye which has been transplanted into the eye socket of an albino rat. The graft took, but showed no evidence of function (Koppányi). G. The fundus of a transplanted eye of the rat, 9 months after the operation (Koppányi). The central artery of the retina has been injected with Berlin-blue. The eye is one of those successful grafts which showed functional recovery.

nerve to the higher optical centers; in other words, is it dependent upon vision? To settle this question I had to go back to the almost discarded method of organ transplantation, and more than that, I had to select the most delicate organ for such purposes—the eye.

Just a few words about the method by which I achieved permanent results, not only with reference to the eye, but also to all the other organs I had to deal with later on. My own and other people's experience taught me soon that the best results are obtained if the graft is not fastened to the host by any artificial means. So I relinquished all sutures, artificial compression, etc., and relied only upon the natural ability of the graft to remain *in situ*. By this technique the wound healing and regeneration could proceed without any delay, having no artificial barriers to overcome. Returning to the eye, I transplanted the eyes of larval and young amphibia on the neck or dorsal region of a host of the same species, and found that those transplanted eye-grafts did not only take but also regenerated a perfect retina and even an optic nerve. The regenerated optic nerve sometimes grew into the nearest spinal ganglion. Although the transplantation of these eyes was successful, it answered my question only negatively. For if I removed the own normal eyes of the host, the transplanted eyes on the back or neck did not prevent the appearance of the dark color characteristic of blind animals, nor did these animals show any ability to copy the color of the environment. I concluded, therefore, that chemical changes set up within the eye and transmitted through the circulation or through non-specific nervous pathways could not be responsible for the phenomenon of color adaptation.

When I undertook the next step in my investigations I could not help feeling a horror at my blasphemy and lack of reverence that I dared to replant the eye into its natural environment, into the eye socket or orbit, and had the audacity to expect, or at least to hope, that I might be able to establish a connection between the visual receptors of the eye and the higher optical centers. Yet I performed the experiment on a large number of fish and amphibia. The results were astonishing. The dark color of the blind animal disappeared in about three months after the transplantation and at about the same time they began to exhibit their lost ability to adapt themselves to the color of their environment. This successful experiment gave me the clue to the whole problem. The color adaptation of fish and amphibia is actually due to the transmission of the color of the environment through the natural optical pathways. Having accomplished this I didn't feel I should stop. The results achieved suggested very strongly that not only the color adaptation but also the vision itself was restored by the transplantation of the eye into the eye socket. Subsequent experiments proved that this assumption was not unwarranted, for the animals with transplanted eyes began to show positive phototaxis to weak light and negative phototaxis or photophobia to strong light. Moreover, they succeeded in chasing and even capturing their prey in a way which only normal animals can do. Blind control animals were never able to learn that. But even if a glass jar was placed between the animal and the prey, the animal with transplanted eye and the normal animal were able to aim directly at the prey outside of the glass jar, whereas blind animals paid no attention to it. The anatomical findings corroborated the biological evidence. The painstaking researches of Professor Kolmer revealed that the histological appearance of the eye graft was almost normal and at any rate all the elements were present which are necessary to optical functioning. He also showed that the cell bodies in the gan-

glionic layer of the retina regenerated nerve fibers which grew through the chiasma into the centers in the mid-brain.

Having solved this problem in fish and amphibia, I proceeded to inquire whether eye transplantation can be successfully carried out in mammals. I chose the rat, for this animal was then available in large quantities and because from surgical point of view its eyes are very readily accessible. Briefly, in this species too I obtained successful results, although in a much smaller percentage than in amphibia. Here, too, I found return of vision and regeneration of the optic nerve of the transplanted eye. Later on even a rabbit was added to the list of the successful experiments. Transplantation of the eye, therefore, in every class of the vertebrate kingdom, is a practicable procedure which may lead to regeneration of the optic nerve and recuperation of vision.

Naturally, the critical scientific world did not let my communications be passed unchallenged. Several and even severe criticisms were heard now and then, and the validity of the results was doubted. This was very fortunate, however, because it led many investigators to repeat my experiments. And it so happened that they came to conclusions similar to mine. I could discuss several papers, all of which affirm my experimental results. Only lately Stone and Ussher reported on return of vision and regeneration of the optic nerve in the transplanted eyes of amblystoma and diemyctylus. On the basis of the experiments just reported, a Belgian ophthalmologist, Weekers, performed the replantation of an avulsed eye in man. The eye was severely injured in the accident and yet the graft took and although vision was not expected, the motility, at least, returned. For cosmetic purposes, therefore, the eye graft became a possibility even in man.

The eye is an organ enclosed in a fibrous connective tissue capsule. This helps the eye graft to protect itself from the invasion of the destroying wandering cells, mentioned already. In connection with other problems I was forced to repeat my transplantation experiments on other organs, similarly protected by a defensive layer. The testis of Urodels, the spleen of the rat, and the liver of the bullfrog were transplanted into the peritoneal cavity and these organs, although not sutured to the host, took with preservation of their original morphological structures. The method which was very efficient in the case of the eye proved to be serviceable in the case of the testis, spleen and liver.

The transplantation of the testis of newts was attempted unsuccessfully by Herlitzka and also by Bresca. I took up the problem again and obtained permanent results. The grafted male gonads of the newts took and even normal spermatogenesis, *i.e.*, the production of ripe spermatozoa, could be observed in the transplants. The male gonads of the newt, *Triton cristatus,* were also transplanted into the peritoneal cavity of females and of individuals of other newts (Pleurodeles, etc.) with similarly satisfactory results.

The spleens of albino rats were transplanted into the abdomen of other animals of the same species. Again the grafts took, essentially preserving their original structure, and certain interesting morphological changes took place in the transplant. The same thing is true of the liver, which was transplanted in amphibia.

Transplantation as a method is a *par excellence* biological procedure and recently proved to be of great value in experimental embryologic investigation. It enables us to discover the hidden potentialities of undifferentiated areas of the embryo; it enables us to find out something about the hidden endochemical activity of an organ; and finally, it enables us to accomplish something there, where organ-regeneration doesn't do the work.

PHYSIOLOGICAL EVIDENCES OF EVOLUTION AND ANIMAL RELATIONSHIP

By Professor CHARLES G. ROGERS

OBERLIN COLLEGE

THE recent work of physicists, chemists and astronomers, dealing with the nature and origin of matter, adds emphasis to the idea that the process of evolution can by no means be limited to what we have been accustomed to call "organic matter," but that it must be applied to our whole universe and that "organic matter" forms only a special case or a series of special cases of the working out of a universal law.

For many years evidences of the evolution of organic forms have been accumulated from a variety of sources. Paleontologists and anatomists have dwelt upon the homologies of various structures. They have pointed to similarities of adult form as indicating similarity of origin and, therefore, of development. Embryologists have shown that there are not only similarities of individual development, but that certain structures have, during the course of their development, taken on forms and functions quite different from those for which they were originally designed.

Little emphasis has been laid upon the contribution which physiology may make in the working out of the general problem. This may be due to the fact that the chief interest of most of our physiologists is not in general biology, but in a very specialized and extremely limited portion of the field, mammalian physiology. This may be another instance in which closeness to the multitudinous details of highly specialized functions has led to a loss of perspective.

It is not the purpose of this paper to present much in the way of new evidence, but by taking advantage of some scattered bits of evidence to call attention to what seems to be a neglected field in the hope that others, better qualified, may continue to develop the point of view.

We have, of course, no information as to how living matter came to be. From what we know of its structure, composition and behavior we may be able to make certain conjectures as to the conditions existing when living matter first appeared. The origin and evolution of living matter is evidently closely associated with the origin and evolution of non-living matter. Here at the very beginning of life we must recognize the fundamental unity of non-living and living. The living matter is made up of non-living constituents. When our friends, the physicists and chemists, have been able to fill in more completely their fabric of knowledge concerning the building up and combining of non-living molecules, we shall be in better position to tell how living matter came to be. Certain facts seem to be sure. There must have been light, and the temperature must have been above the freezing point of water and below the coagulation point of the particular compounds which make up the bulk of the living substance. The evolution of matter had gone so far that there already existed the elements of the lower atomic weights and many of the combinations of these. Oxygen, carbon dioxide, nitrogen and simple nitrogen compounds were in the atmosphere, along with water vapor.

The molecules of inorganic crystalline substances have a definite configuration. They are, under the conditions existing.

stable structures. The molecules entering into the composition of living matter may also be stable, but the configuration of the aggregate which we call living substance is very unstable. From the growth of the salt crystal in saturated solution to the growth of the living substance is a long step, for the two are wholly different processes. How may the latter have been brought about?

Try to imagine the conditions upon our planet before any life appeared. The sun, the center of our solar system, was much younger than now. Astronomers tell us that the stars have a definite life history: that they have a beginning, youth, middle age, old age, and finally cease to be. Our sun appears to be well along in its cycle. It has passed through that period in which it radiated most energy. These radiations have been and still are in part electrical, in part visible light and ultra-violet radiations, in part infra-red rays, in part radiations of very short wave-length. The younger stars, the whitish and the bluish-white ones, are characterized by extensive radiations in the ultra-violet region of the spectrum. Such radiations were presumably more abundant upon our earth in the earlier days than now. Certain radiations of very short wave-length, emanating from some unknown source, are even now detectable in our atmosphere. They may have been and probably were more abundant at an earlier period. Their presence is held to be indicative of the continuous production of helium, hydrogen, oxygen, etc., out of the raw materials, the electrons.

Imagine the land, entirely devoid of vegetation of any sort, made up of binary combinations of elements, at a tropical temperature, water-soaked by frequent rains, covered by an atmosphere heavily laden with moisture and containing oxygen, a higher content of carbon dioxide than is now known (the product of volcanic activity), nitrogen and very simple nitrogen compounds. Imagine heavy storms—water rushing down through the valleys into the sea and on its way dissolving various inorganic substances, and carrying along relatively less soluble material in the form of finely divided particles, a suspension so finely divided as not readily to settle out upon standing—colloidal material, if you please. Let the energy of the sunlight with its excess of ultra-violet rays bombard this colloid-like system. At the colloidal interfaces adsorptions of carbon dioxide, gaseous nitrites, oxygen, etc., must occur. At these interfaces these simple substances are brought into molecular relations with each other. A simple catalytic system is at work. Out of the complex it is difficult not to assume the building up of ternary compounds of carbon, oxygen and hydrogen, such as formaldehyde and simple carbohydrates, and then of simple quaternary nitroenous compounds, such as formamide. New substances come into being because of the activity of the colloid-like solution as an energy transformer. The elements involved are the carbon, oxygen, hydrogen and nitrogen; then molecules of sulphur, phosphorus and iron are added to the combination. Water, the universal solvent, is not only the solvent in the living substance, but has an important part in its structure, for it has become an integral part of the colloidal substance.

The colloidal material responsible for bringing about these first syntheses may be thought of as a simple catalyst, very generalized in its character and behavior and in the products of its energy transformation. Some of the earliest appearances of what we think of as living matter must have been the combination of molecules into forms capable of acting as energy transformers—substances which could make use of the energy of the sunlight in effecting various molecular combinations. We have at the present time such a substance in chlorophyll. There is no evidence that the

earliest synthetic agent of this sort was green in color. In fact the suggestion has been made that the green color has been developed as a protective device to assure the non-destruction of a more fundamental catalytic substance by the light rays.

From the simplest colloidal complex capable of self-continuance to the simplest amoeba with which we are acquainted represents a wonderful evolutionary history, which may well have occupied as long a time as the evolution from amoeba to man. During this period there must have been elaborated amino-acids and various combinations of these to form proteins, various carbohydrates, fats, nucleic acids and enzymes. It would be absurd to assume that all the bits of matter of the kind described, in which organic syntheses occurred, could survive. Many of them would carry on within themselves processes which would prove to be self-destructive. It is interesting to note that only those forms have survived to the present on which there were developed membranes to serve as separations of the living substance from the liquid environment. Evidently much can be said about the cell membrane as a factor in survival. Various cell mechanisms came into being. There were developed mechanisms for regulation of water content, for the selective and constructive work of secretion, for cell division, for ensuring in the daughter cells living matter of the same sort as that which composed the mother cell. Survival came not to be a haphazard affair, but the result of an orderly series of physical and chemical phenomena. These various mechanisms did not all come into being at once. They did not always appear, perhaps, in the same order. They did not always take the same form, nor were they always made up of the same components. The bits of unstable matter in which synthetic processes occurred were in constant interaction with their environment. Since there were variable environments, there were variable synthetic complexes. We have been accustomed to speak of the origin of living matter. It would be better, and probably more in line with the facts, to speak of the origins of living matter. In various places at the same time such syntheses may have occurred. Also, there is nothing to oppose the suggestion that at many times, in many places, under a great variety of conditions, such combinations of matter capable of undergoing spontaneous change and of acting as energy transformers may have had independent origin. This would not only make great variety of living matter possible; it would make it inevitable.

It would be safe to assume, too, that these different bits of living matter did not exist together in a perfectly harmonious fashion. Some of them were inimical to others. Some may have played such parts as are now played by the filterable viruses. Only those forms of living matter could exist which developed some form of immunity against the attacks of other unfriendly forms.

The forms of living matter capable of carrying on these organic syntheses, and of maintaining their own integrity, are those which appear as colloidal systems of a complicated nature, so that they appear at one and the same time to partake of the nature of true solutions, emulsions, colloidal sols and suspensoids, and to have so delicate a colloidal balance as to be rather readily transformed from the liquid sol condition to the more viscid gel condition, and vice versa.

One of the very strongest evidences of the essential unity of living matter is that we have no knowledge of life apart from protoplasm. This protoplasm, from whatever source, is always a substance containing water, salts in solution, and composed largely of proteins, which are present either in the form of an emulsion or as a suspension.

This early living matter originated in the sea, or, perhaps more strictly, in the littoral waters. It was, therefore, at the time of its origin adapted to the existing conditions. Otherwise it could not have continued to exist. What were these conditions? It seems that we may be able to reconstruct to some extent a picture of the situation. Living forms adapted themselves to their environment in a variety of ways. Let us mention a few of them.

(1) *Temperature:* The temperature of the organic matter was essentially the same as that of the water in which it originated. It was, therefore, of a temperature between the freezing point of water and the coagulation point of the colloidal complexes of the living substance. The temperature of the water must have shown then, as now, a daily cycle, rising during the daylight hours until the latter part of the afternoon, and then falling during the hours of darkness until the early morning. Such a cycle of temperature changes now exists not only in the waters of the tropical ocean, but in the bodies of the so-called warm-blooded animals. It would hardly do to say that this daily temperature cycle of the higher animals is a direct hangover from the daily temperature cycle of the early ocean, and yet it might be.

(2) *Concentration of Salts:* The sea water contains at the present time about 3 per cent. of salts in solution. This reppresents an accumulation of millions of years. When matter first became organized into forms capable of carrying on orderly energy transformations and of providing for self-continuance, the water of the sea was much less salt than now, though it may have been somewhat more salty than present-day freshwater streams and lakes. The living matter then was adapted or adapted itself to the conditions existing.

An examination of the body fluids of various groups of animals reveals the fact that in the animal kingdom there has been a rather steady gradation in complexity from the very simple to the very complex as we pass from the lower forms to the higher. It is a long step from the conditions existing in the body fluids of some of the simpler animals—and which must have existed in the body fluids of the earlier metazoa, up to the exceedingly complicated conditions which now exist in the bloods of the mammals. In the lower and earlier forms the body fluids consisted of water in which were dissolved some small amounts of salts. In the bloods of the higher animals of to-day water is still the solvent in which there are to be found in solution:

$$\text{the } \left.\begin{array}{l}\text{chlorides}\\\text{sulphates}\\\text{carbonates}\end{array}\right\} \text{ of } \left\{\begin{array}{l}\text{sodium}\\\text{potassium}\\\text{calcium}\end{array}\right.$$

proteins
  serum albumen
  globulin
  fibrinogen
prothrombin
antithrombin

foods
  amino acids of a number of kinds
  fats or fatty acids and glycerine
  sugars

oxygen
carbon dioxide

wastes
  urea
  uric acid
  creatine
  creatinine

hormones
  gastric and pancreatic secretins
  thyroid
  adrenal
  pituitary
  ovarian
  testicular
  thymus
  pineal

antibodies for measles, mumps, smallpox, typhoid, scarlet fever, etc., etc.

The body fluids pass through a regularly graded increase in complexity which may be briefly outlined as follows:

Water, containing the salts of the sea in solution.

Hydrolymph, a watery fluid which carries nutriment to organs and tissues and removes wastes. This fluid sometimes contains no food substances in solution, though it may hold them in suspension, or in some cases it may contain dissolved proteins or their products. As a rule it has no respiratory function other than that which might be carried on by the water alone.

Haemolymph is a circulatory medium less watery than the hydrolymph. It contains a richer supply of proteins. It is not only nutritive in function, but also frequently respiratory in character by virtue of the respiratory pigments which it contains, and corresponds to both the blood and lymph of the higher animals.

Blood, which is the chief circulatory fluid of the higher animals. It is the most highly differentiated and complex circulating mechanism found in the animal kingdom and serves in the following functions: to carry to every part of the body the materials for its sustenance; to carry away from the tissue cells all wastes; to carry to all parts of the body hormones and internal secretions; to serve as an agent in the temperature regulation of the body; and to protect the organism from invasion and destruction by microorganisms.

Osmotic Pressure of Body Fluid

As the salt content of the sea water has increased, those animals of the simpler types which have remained in the sea have gradually adjusted themselves to the changing conditions of their environment. One may almost say that the bodies of these lower animals are wide open to the sea. As a matter of fact this is not strictly true, for it appears that most of these lower forms of animals possess body fluids of very slightly higher osmotic pressure than that of the sea water in which they live. The relative total salt content of sea water and of body fluids may readily be compared if the depression of the freezing point of the liquid below that of distilled water be determined. This depression of the freezing point can be expressed in terms of degrees Celsius or translated into atmospheres of pressure or concentration of solution, as one may prefer to do.

Reference to the table indicates that the forms showing the lowest osmotic pressures (least depression on freezing point) are the fresh-water molluscs, worms and crustacea. Then come in ascending order the reptiles, amphibia, fresh-water bony fishes, mammals, birds, marine bony fishes, Atlantic Elasmobranchs, Atlantic invertebrates, Mediterranean Elasmobranchs and Mediterranean invertebrates.

An analysis of the facts seems to indicate that there is some causal relation existing between the osmotic pressure of the sea water and the osmotic pressure of the bloods of the different groups.

Depression of Freezing Point in Degrees Celsius

	Mediterranean Sea	Pacific Ocean	Atlantic Ocean	Fresh Water	Terrestrial Animals
Sea Water	– 2.29	– 1.924	– 1.82	– 0.03	
Mammalia			– 0.64—0.74		0.56—0.60
Aves					0.66—0.75
Reptilia					0.46—0.56
Amphibia					0.56—0.76
Pisces	– 1.04—1.05	– 0.762	– 0.75—0.86	– 0.51—0.68	
Elasmobranchia	– 2.29—2.44		– 1.87—2.03		
Cyclostoma		– 1.966			
Mollusca	– 2.24—2.44			– 0.15—0.21	
Insecta					– 0.95
Crustacea	– 2.29—2.36		– 1.82—1.90	– 0.49—0.80	
Annelida				– 0.43	
Coelenterata	– 2.195				

Undoubtedly the sea water in which life originated was relatively dilute as compared with the sea water of the present time. This sea water became more and more concentrated as various salts were washed down from the land into the sea. At various periods some of the animals living in the sea migrated up the streams and came to live in water which was less concentrated in salts, others emerged from the sea and took up a terrestrial habit of life. It is possible that there was a period in which the salt concentration of the sea water increased rapidly or that some other factor led to a great migration or series of migrations of animals from the sea. Overpopulation of restricted portions of the sea may possibly have been a factor. At any rate, evidence is not lacking that the ancestors of many species, representing several phyla, left the waters of the sea at nearly the same period—a sort of organic explosion. The immediate causes of such a migration must have been physiological. Those animal lines which remained in the ocean have been for generations continuously subject to the gradually increasing concentration of salts in the sea water. The accompanying figure (Fig. 1) presents in a graphic form a brief summary of information concerning the freezing points, and therefore the osmotic pressures, of the body fluids of various animal groups, and a suggestion is offered as to the possible explanation of some of the facts. It will be noted that, in this figure, depressions of the freezing points of bloods and of sea water are represented as abscissae, and that duration of time is indicated as ordinates. No effort is made to indicate any definite lapses of time. The fresh-water molluscs show a depression of the freezing point which indicates either that they migrated from the sea into the fresh water at some very early period or that they have developed little power to maintain in the body fluid a salt concentration different from that of their environment. The fresh-water worms show a decided increase in the salt content of the blood. The reptiles show a salt content slightly higher than that of the fresh-water worms. The fresh-water fishes, the mammals, the amphibia, the birds, all have salt concentrations of very nearly the same values, which slightly overlap each other and which are only very slightly below the salt concentrations of the bloods of the marine bony fishes taken from the North Atlantic. It seems entirely possible that the ancestors of these forms so closely grouped must have emerged from the waters of the sea at approximately the same period, as far as salt concentration of the sea is concerned. The mammals and birds apparently have attempted to maintain in their body fluids through all the succeeding generations approximately the same concentration of salts as that to which their ancestors were accustomed in their original marine habitat. The fresh-water fishes and amphibia show a somewhat wider range of salt concentrations than do the birds or the mammals. This condition can, perhaps, be accounted for by the fact that the animals have for the most part lived continuously in an aquatic environment. They have maintained with more or less exactitude the salt concentrations of the bloods of their ancestral forms, concentrations which were presumably very similar to the concentrations of the sea water in which they lived. The marine fishes, both of the open ocean and of the Mediterranean Sea, show osmotic pressures a little less than one half the concentration of the water in which they live. The bloods and body fluids of the marine invertebrates, however, have salt concentrations which equal or are very slightly in excess of the concentration of the sea water. Just how far it is justifiable to seek to explain the salt concentrations of the bloods of all terrestrial

forms upon this basis is, of course, somewhat uncertain. It appears in each case that the blood is in a condition of equilibrium with the external medium, even though it may differ from it to a considerable degree. It can also be shown that any change in the osmotic pressure of the external medium brings about a corresponding and compensating change in the osmotic pressure of the blood, to a greater or lesser degree in the different groups, until a new equilibrium is established. Such an equilibrium is established and maintained by the cells which come into contact with both liquids, blood and water, namely, the epithelial cells of the gills. The evolution of cells and cell membranes capable of maintaining such differences of osmotic pressure as are shown in these cases presents a problem worthy of much further study.

It is not necessary at this time to go into a discussion of the physiology of the adaptation of an animal to the osmotic conditions of its environment. When living matter first appeared in the water of the sea it was undoubtedly adjusted to the salt content of the water as it existed at that time. The salt content was being continually increased through the addition of salts washed down from the land into the sea. These additions must have accrued very slowly, indeed. The fact that the living organisms continued to exist is itself an indication of the fact that there was a continual adjustment of the organisms to the increased concentration. This adjustment has continued until it is now found that organisms have become adapted to living in a salt solution, the concentration of which may be equal to or in excess of that of a five eighths molecular NaCl solution.

But not all animals live in the sea. At different periods in the earth's history there have been migrations from the sea to the fresher waters, and also from the sea to the dry land. Many of these migrations took place relatively early in the history of animal life. The animals taking part in these migrations evidently made the attempt to continue in their bloods the cellular environment which had been theirs before the migration. This environment involved both water, containing a certain concentration of salts, and salts in definite relative proportions to each other. The blood plasma of the higher animals, therefore, represents the original aquatic environment of the cells as to the total concentration of salts, and should contain all the elements originally entering into the composition of that environment. As we shall see, it may contain much more than the original environment, for during the ages there have been taken on new substances, providing for new functions, or great extensions of old ones. (For example, the development of the thyroid gland in the higher animals may be explained as an attempt on the part of the organism to preserve in the body fluid of the animal the iodine content of the sea water, and so regulate the metabolic activities of the cells.

Composition of Body Fluids

Unfortunately, complete analyses of the body fluids of the lower animals are not yet available. We have good reason to believe, however, that they approach more nearly the composition of the sea water than do the bloods of the higher animals. Only very recently has the importance of the substances existing only in very small amounts in body fluids been recognized. Such substances may exist in the body fluids of the lower, invertebrate animals. Up to the present they have not been recognized.

In all forms of the metazoa in which body fluids exist there is a remarkable balance between the relative numbers of molecules of sodium, potassium and calcium, of the circulating medium, the ratio being in general of the order 100 : 2.2 : 1.5–2.5. In the sea water mag-

nesium salts occupy a prominent place, and they appear in the bloods of the lower forms also. Among the higher animals the magnesium plays no important part, and it would almost seem that the ancestors of these animals had taken their departure from the sea before any considerable amount of magnesium existed in the sea water, or that these organisms have the power to exclude magnesium from their bodies. It is to be noted, however, that while the body fluids of many groups of animals contain sodium, potassium and calcium salts in essentially the same proportions as those in which they exist in sea water, the body tissues have the power to store up or to exclude these substances. Such storage or accumulation may occur whether the organisms be unicellular or multicellular, and indicate a gradual specialization upon the part of the secreting cells. Such specializations of a chemical sort appear among diatoms, desmids, Foraminifera, Radiolaria, silicoflagellates, sponges, Alcyonaria, Anthozoa, Bryozoa, etc., as well as in the higher groups. The fact that the specialization is very real is shown by the tremendous amounts of material secreted from very dilute sea water. For example, Clark has shown that the protozoa of one family deposit 1.4×10^9 metric tons of calcium per day. Numerous other similar cases might be mentioned.

Hydrogen-ion Concentration of Sea Water and Body Fluids

It is only within comparatively recent years that biologists have come to appreciate the importance of some of the less evident conditions which enter into the environment of living organisms. One of these has to do with the degree of acidity or alkalinity or, as we more frequently refer to it, the hydrogen-ion concentration of the medium. The sea water, by means of the various salts which it contains, maintains a very definite and very constant alkalinity. This is best expressed in terms of Sorensen's nomenclature, in which the symbol pH 7 represents the neutral point, and in which a numerical reduction means an increase in acidity, and a numerical increase a reduction in acidity and an increase in alkalinity. It has been found that the following figures represent existing conditions in animals of the phyla mentioned:

Sea water	pH 7.09–8.02
Body fluids:	
Coelenterates	8.48
Worms	7.25–7.79
Echinoderms	7.27–7.76
Molluscs	7.23–7.54
Arthropods	7.38–7.62
Tunicates	6.56
Fishes	7.54
Mammals	7.40–7.62

It is to be noted that in almost every case the pH is on the alkaline side of neutrality. Measurements made upon the living protoplasm of various cells indicate that the protoplasm is, on the whole, more acid and less alkaline than the medium in which the cells live. Amoeba protoplasm has a pH of 7.6; the protoplasm of four species of Echinoderm eggs, one species of Tunicate egg and one species of Polychaete worm egg, all show a pH of 6.6. When these eggs died and began to cytolize the pH increased to 4 or 5.

Blood Pigments

Increase in size and complexity of metazoan bodies was made possible only through the development of mechanisms providing for the rapid distribution throughout these bodies of the required supplies of food and oxygen, and for the elimination of wastes. Increase in size and complexity of the animal body has been associated with a relative reduction in the volume of blood contained within the body, and the activity of the animal seems to be correlated with the ability of the blood to carry oxygen. This re-

duction in volume has been coincident with developments along two lines: first, increase in the efficiency of the circulatory apparatus, so that the fluid is carried more rapidly through the body; and, second, an increase in the efficiency of the blood as an oxygen carrier. It will be remembered that oxygen and carbon dioxide are soluble in small amounts in water or in body fluid, but these amounts are insufficient to meet the needs of an active organism. During the course of evolution proteins, which have a remarkable power of forming easily dissociable compounds with oxygen at ordinary atmospheric pressures, have developed. These are the so-called blood pigments. Some of these are much more effective as oxygen carriers than others. The oxygen-carrying power of the blood will then depend upon the particular pigment which it contains and upon the amount of that pigment which is present. Named in order of importance these pigments are:

	Color	Metal present	Distribution
Haemoglobin	red	iron	widely
Haemocyanin	blue	copper	molluscs, crustacea
Haemosycotypin	blue	copper, zinc	molluscs
Chlorocruorin	green	iron	worms
Haemerythrin	red	iron	worms
Achroglobin	colorless	manganese	molluscs
Pinnaglobin	colorless	manganese	molluscs

Of these pigments, haemoglobin is by far the most important. It is a protein substance containing probably as many as two hundred amino-acid links in its molecule, which has been estimated to have a molecular weight of about fifty thousand. Of this substance there is a great amount produced daily by living animals, the amount being built up daily by human bodies being estimated at ten thousand tons. This substance represents the highest degree of evolution by living matter of an oxygen carrier. The substance which ranks next to haemoglobin as an oxygen carrier is haemocyanin. This has about one fourth the oxygen-carrying power of haemoglobin. The haemocyanin molecule is one of almost unbelievable size, with a molecular weight of five millions. This figure is estimated to be correct to within five per cent.

All the blood pigments of the lower animals are dissolved in the blood plasma, but among most of the vertebrates the haemoglobin of the blood is held within the walls of minute cells, the red blood corpuscles. It will be readily acknowledged that material dissolved in the blood plasma would be more likely to be lost to the organism than material carried in cell envelopes. It seems safe to assume that the habit of enclosing small amounts of haemoglobin in envelopes and of transporting them through the vascular system is an acquired habit. The suggestion is made that this habit is an outgrowth of a possible symbiotic relation that may have existed far back in ancestral history, in which pigments similar to the pigment radicle of haemoglobin may have been discarded by various tissue cells as wastes, only to be picked up as possible food substances by invading protozoan cells. These cells, wandering about through the tissues, would have served to carry the pigment, with its combined oxygen, to the more distant parts of the organisms, where under reduced oxygen tension the oxygen would be released, to the benefit of the host. This habit, once acquired, can easily be imagined to have led not only to a conservation of pigment material once cast aside as waste, and now found valuable, but to an increased production of this valuable pigment material for its own sake as a factor in survival.

Blood Coagulation

A physiological process of great importance to the individual, and likewise to the race, is that of blood coagulation. One needs not to be told that any considerable loss of blood is detrimental to the life of an individual. This is especially true in the case of those animals in which the percentage, by weight, of blood has been greatly reduced. In the higher organisms the process of clotting involves a very carefully balanced series of chemical reactions, the explanation of which involves excursions into analytical, organic, colloidal and physical chemistry.

If it is permissible to judge from what may be seen in a survey of the clotting function, passing from the lower animal forms toward the higher, it is possible to say that very early in animal history there began to be developed methods of conserving the blood supply. At first these methods were very simple. One very early method consisted in the massing of the colorless corpuscles of the body fluid at the point of injury. These cells were equipped with long protoplasmic processes or arms reaching out from the central body mass. The processes of one corpuscle became entangled with those of another and another and another, until there was a purely mechanical blocking of the blood flow. Such blocking was not, however, very efficient, and a great deal of blood might be lost before the flow became checked.

Apparently the next step in the process of evolution occurred when the entangled cells began to undergo a sort of chemical change which left them as an agglutinated mass of protoplasm in which all semblance of cell boundaries had disappeared. This stage appears to have been closely followed by one in which there occurred within the cell bodies the secretion of a substance which, when released from the entangled, agglutinated cells, gave rise to a fibrin-like substance, cell fibrin. This substance is probably not at all related to the substance known as fibrin, which is a normal component of mammalian blood. The cells which secreted this cell fibrin were somewhat more specialized than the blood cells which had preceded them. They were more sensitive to changes in their environment, and certainly did a type of chemical work which had not hitherto been accomplished. Under conditions so changed as not to be normal, these cells disintegrated and gave up to the blood stream the fibrin-making material which they contained. The swelling and entangling of this material with other elements of the blood constituted a more adequate block against blood loss. Another step was taken when there was added to the chemical constitution of the plasma a substance which could be made to coagulate under the appropriate conditions. At first, this coagulation of the plasma was very slow and uncertain. In the higher animals the coagulation of the plasma has now reached a very high degree of perfection, and involves the interaction of substances in solution in the plasma with substances produced in tissue cells, which are released when the blood vessels are injured, and substances produced in certain of the blood cells, which are exceedingly sensitive to changes in their environmental conditions. This chemical mechanism is now under normal conditions so effective as to bring in a few seconds results which in the lower forms would have required as many minutes or an even longer period.

Blood Reactions

A line of investigations which has already yielded some positive results, and which promises much for the future, is that of precipitating and agglutinating effects of various blood sera upon other bloods. It has been shown that, while during the course of evolution the de-

scendants of a common ancestor may have undergone such changes of form and structure as to make it almost impossible to point to direct evidences of common ancestry, there still remain in the bloods of many animals some common property or properties which may render it possible, through biochemical reactions, to determine their relationships. Professor Nuttall writes:

> A perusal of the pages relating to the tests made upon the many bloods I have examined by means of precipitating anti-sera, will very clearly show that this method of investigation permits of our drawing certain definite conclusions. It is a remarkable fact, as I stated on a former occasion with regard to my results with the Anthropoidea, and this applies to other groups of animals, that a common property has persisted in the bloods of certain groups of animals throughout the ages which have elapsed during their evolution from a common ancestor, and this in spite of differences of food and habits of life. The persistence of the chemical blood relationship between the various groups of animals serves to carry us back into geological times, and I believe we have but begun the work along these lines, and that it will lead to valuable results in the study of the various problems of evolution.

In 1907 it was pointed out that there is also an incompatibility between the bloods of different human beings. Since 1910 human beings have been classed in four groups, the blood of only one of which, group four, including about 40 per cent. of the population of western peoples, can be used for transfusion into members of all groups. There is still the possibility that these groups may, after further study, be subdivided.

More recently, Landsteiner and Miller have shown that the haemagglutinins form even better means for distinguishing blood relationships than the precipitins. Racial differences between whites and Negroes are less, if existent, than those between the bloods of man and the anthropoids. Serological differences between man and the lower monkeys are the same as those between anthropoids and the lower monkeys. Also they were able to show from a study of thirty-six species of lower monkeys that there exists a correspondence between the distribution of a certain haemagglutinin and the place of the species in the zoological system. This is evidently a line of investigation which should be followed through with most extreme care and thoroughness.

Chemical Actions in Living Matter

It is customary to speak of the chemical changes which take place in living matter by using the term "metabolism." This includes a great variety of chemical operations, such as oxidations, reductions, deaminizations, coagulations, digestions, syntheses, etc. These are operations which would not occur at all, or only very slowly, except for the presence and activities of certain catalytic agents which we call enzymes. Catalytic actions are characterized by the fact that the chemical composition of one of the products found at the end of the reaction is the same as that of one of the initial substances. Such reactions have been held to be quite specific, but specificity here appears to be more a quantitative than a qualitative relation. For all enzymes the time required to bring about small, equal changes in the substrata is roughly inversely proportional to the concentration of the enzyme. The enzymes are inhibited in their activities by the presence of the products of reaction; they are relatively unstable and retain their catalytic power only within a very limited range of temperatures, and within a rather narrow range of hydrogen-ion concentrations. They have been found to bring about balanced actions, *i.e.*, to operate both to break down and to build up. They are thus able to break down food substances into molecules capable of diffusing through membranes into cells, and then to build up within the cells these small molecules into the more complex carbohydrates,

fats and proteins found in living matter. They also take part in the building up of the various secretions, poisons, etc., produced by many animals. Among the higher animals the number of enzymes is very large, and the work which each does is very narrowly limited. Every cell, tissue and organ of each individual organism is a chemical laboratory in which a considerable variety of chemical operations takes place. The character of the processes depends upon two sets of factors: first, the nature of the substances acted upon, and second, the nature of the enzyme taking part in the reaction. It seems very likely that the differences between the various proteins which characterize unlike species of animals may be accounted for by the fact that the enzymes responsible for the synthesis of these substances are very slightly different from each other, although very similar in many respects.

A complete list of the enzymes occurring in any one of the higher animals would be quite extended. As to the number of enzymes to be found among the lowest animals we have little information. One reason for our lack of knowledge is that an enzymic analysis of animals of microscopic size is not very easy; a second reason is that only comparatively recently has the possible significance of such an investigation been apparent. It is known that the enzymes of the lower forms are more generalized, less specialized, than those of the higher animals. For example, among the protozoa, a trypsin-like enzyme, which acts upon proteins, is found. There are only very doubtful evidences of the presence of pepsin, and specialized enzymes capable of acting upon starches, sugars and fats probably do not occur at all. Among the Coelenterates pepsin, as well as trypsin, occurs; and lipase, amylase, maltase and, in some cases, glycogenase, are present. Among the worms and Echinoderms a few more enzymes make their appearance, and among the Mollusca and Arthropoda a still larger number is found. Among the vertebrates others are added. It appears, therefore, that as one passes in review from the lowest to the highest animals there is an increase in the number of enzymes, and in the degree to which these enzymes are individually specialized for the building up of definite substances out of the raw materials. It may be possible that the high degree of differentiation found among the so-called higher animals is simply an indication of the high degree of specialization to be found among their organic catalysts. The suggestion has been made that enzymes are as varied as the substances constructed by the metabolic activities of animals.

Excretion

It is possible to study in a similar way the processes of excretion and to show that there has been a real evolution in the disposal of wastes. Among the protozoa three methods for the disposal of wastes are found. They may be diffused through the cell wall; they may be deposited in the protoplasm as inert, granular precipitates, or they may be eliminated in solution by the liquid thrown off from the contractile vacuole. The protoplasm of the protozoa has a higher osmotic pressure than that of the water which forms their natural environment. There is, therefore, a continual endosmosis. In the case of marine forms the difference in osmotic pressure between organisms and sea-water is less than in the case of the fresh-water forms. There is, therefore, in the marine forms less need for a water-regulating apparatus. Among the fresh-water forms the contractile vacuoles reach their highest development, and serve to carry off the excess of water which diffuses rapidly into the cells. The water excreted carries with it dissolved substances, such as carbon dioxide, uric acid, etc.

Among the lower metazoan forms there are, in addition to the elimination by diffusion of soluble substances through the membranes of the body wall, wandering cells which take up granular wastes produced by metabolic activity. The wandering cells carry these to some exposed portion of the body, such as a gill filament or to some other area, work their way to the outside, and there disintegrate. This process is referred to as intracellular excretion. The waste materials are then washed away. Or the wandering cells may carry their burdens of wastes to some relatively inactive corner of the animal body, and there deposit their load of rubbish, as in some old attic. There are thus formed masses of accumulated granular wastes, frequently pigmented, which are very characteristic of such forms as the starfishes. This is termed storage excretion.

Among the worms and higher forms these primitive types of excretion become more highly elaborated, and the processes centralized in special organs, nephridia or kidneys, developed for the purpose. The cells upon which devolve the function of forming the excretion granules become, among the worms, very numerous, and the nephridia apparently have the power to carry off such granules as are given over to the coelomic fluid by the disintegration of the excretophore cells. At the same time some of the cells of the nephridial tube appear to be specialized as secretory cells, apparently comparable to some of the glandular cells of the tubules of the mammalian kidney.

Among the higher terrestrial animals there is added to the excretory work of the kidneys another function, that of conserving the water content of the body. This is accomplished through the resorption of water which has filtered through the glomerulus and is on its way to be passed out of the body.

It is interesting to note that while the character and efficiency of the excretory organs have undergone a great evolution, the nature of the substances excreted by the higher forms is not very greatly unlike that of the substances excreted by the lower forms. In this there is evidence that the end products of the metabolism of different animal groups are strongly similar. Among molluscs, for example, there appear as excreted products inorganic salts, creatine, creatinine, taurine, ferric salts and uric acid. Among the Arthropods uric acid is occasionally found and guanin is the most important excreted substance. Among the higher animals urea appears in the urine in the place of uric acid.

Chemical Regulation

In the bodies of adult vertebrates there are certain substances known as hormones, which have profound effects in the regulation of various physiological activities. These substances are produced in any individual in very minute amounts, but must be present if the organism is to function normally. The hormones are relatively simple chemical compounds of the nature of drugs, since they do not lead to the production of antibodies; they are not enzymes, since they are not readily changed by conditions which render enzymes inactive; they are of small molecules, since they diffuse rather readily through animal membranes. Most interesting and important, however, is the fact that the hormones have uniform and constant effects, no matter by what organism they are produced. In fact, some of them have been synthesized in the laboratory and are just as effective as those produced under natural conditions. Our knowledge of these substances is limited almost entirely to those occurring in the higher vertebrates, such as the secretions of the thyroid, parathyroid, pituitary, pineal and adrenal glands. There is evidence that adrenalin or a substance closely allied to it occurs in the leeches,

in some others of the higher worms and in some molluscs; but concerning the existence or rôle of other endocrine secretions among the invertebrates very little is known. The evolution of the vertebrates appears to be very closely associated with the development of these chemical regulators. At any rate it seems clear that the highest types of living animals are to a very great degree dependent upon the secretions of these ductless glands for the positions which they occupy in the animal scale.

Reproduction

In no single physiological function is there clearer evidence of evolution than in that of the continuance of the protoplasmic line which we commonly refer to as the species. From the simplest division of an amoeboid cell to form two daughter cells, through the stages of incipient sexualism, up to the most highly developed reproductive processes of the mammals, is a long story of biological attempts to ensure the continuance of the race, to reduce the wastage of energy involved in the building up of valuable germinal material and to conserve the lives of individuals once started on their course of development.

There may be included in this story: the increases in the number of eggs produced, up to several millions per female; the very great excess of sperm produced in most species of animals; the provisions made for ensuring the fertilization of the eggs; the various provisions made for the protection of the eggs during their period of development, such as egg laying in strings or masses, nest building, and egg attachment to parent or to some solid object; increase in the amount of food yolk included within the egg, so as to lengthen the period before hatching; the secretion of shell and albumen coats upon the eggs; the retention of the eggs within the body during a period of development; the gradual evolution of the placentate method of nourishing the embryo during intra-uterine development, and a lengthened period of infancy during which the young are still nourished by maternal secretion.

Nature has experimented upon a vast scale, and we have no reason to believe that the experimental period is passed. It seems clear that some way may yet be found by which the reproductive process may be carried on without the necessity that the reproductive functions or structures shall interfere with other organic functions in such a way as to be inimical to the life of the individual.

Death

As a final line of evidence of evolution from the physiological side there may be mentioned the appearance of death. There is ample reason to believe that natural death is a habit acquired long after matter came to be living. Death is the price which all higher animals must pay in return for high differentiation of cells, and, therefore, of high physiological efficiency.

Reproduction among the protozoa consists in the division of the cell into two. Even among the protozoa the mechanism for such cell division may be extremely complicated. In some forms this process may occur for thousands of generations without any conjugation of different individuals, or endomixis, or any indication of senescence upon the part of the cells. Apparently the process may continue indefinitely. The protoplasm is apparently immortal—barring accidents, and provided that environmental conditions be maintained in a favorable condition. Accidents do occur, however, and environmental conditions for the great mass of individuals prove unfavorable. Food and oxygen supplies fail, poisonous wastes accumulate and check growth and antagonistic organisms prey upon them. Thus the overpopulation of the earth by a single species is prevented.

Similarly, some of the lower metazoa, the sponges, flat worms and some coelenterates reproduce by simple fission or by budding off a portion of the body which reproduces the whole. Here again is no place for death. No residue is left behind in the passage from one generation to the next.

In a similar sense it may be said that the germ cells of the higher animals are immortal. The fertilized egg cells give rise to cells of two sorts, those which form the soma, and germ cells. These germ cells give rise to other germ cells and other somata. This process is repeated over and over and forms a continuous cycle. The soma perishes, but the germ cells live on.

It has been found possible in experiments upon tissue cultures to isolate small bits of embryonic tissues of various kinds in artificial media and to cultivate and keep them alive under observation for a long time. Interesting it is that such cells may retain their embryonic characters for many times the natural lifetime of the species which they represent. It appears probable, therefore, that the cells of all the essential tissues of the metazoan body, when so placed separately as to be provided with the appropriate food in the right amount and to have the deleterious metabolic wastes promptly removed, are potentially immortal. The cells so cultured do not become highly differentiated so long as they grow out of association with other tissue cells. It, therefore, appears that differentiation of tissues along special lines for special purposes is conditioned by association with other cells, and inevitably leads to conditions which result in senescence and, finally, death.

Study of the growth relations of fishes and other animals by Bidder shows that a water-borne animal may continue to grow almost indefinitely, but that swiftly moving land animals must maintain a definite relation between body weight

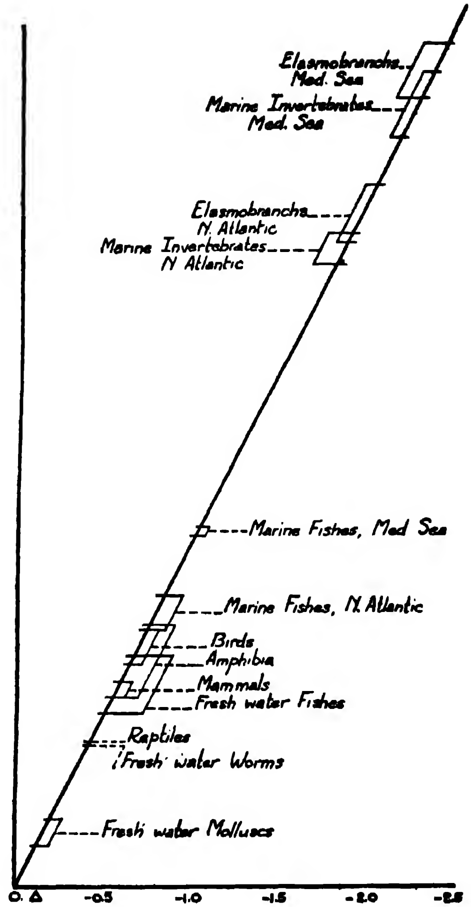


FIG. 1. A CHART INDICATING THE SALT CONTENT OF THE BLOODS OF LARGE GROUPS OF ANIMALS AS DETERMINED BY THE FREEZING POINT METHOD. Abscissae indicate freezing points; ordinates indicate durations of time during which the salt content of the ocean has been increasing from a minimum to the values now found in the Atlantic and in the Mediterranean Sea. The suggestion is made that the grouping of fresh-water fishes, mammals, amphibia, and birds may have some relation to the concentration of salts in the sea when the ancestors of these animal groups left their marine habitat. The diagonal may represent the rather steady and continuous increase in the salt concentration of the sea water with the passage of time. Rogers, "Text Book of Comparative Physiology," Copyright, 1927, by the McGraw-Hill Book Company, Inc. (Reproduced here by permission.)

and the cross-sectional areas of their bones and muscles. Before puberty, men and plaice show additions to weight, in equal intervals of time, in geometrical progression. After sexual maturity additions in weight occur in arithmetical progression. In the fish the annual increment remains positive; in the man the difference in weight actually becomes negative, and from twenty-eight years of age on there is a constant net loss of weight of protein, amounting annually to about 0.8 per cent. of the weight at twenty-eight years. The mechanism of the adult body is set after puberty to a certain annual balance of profit and loss: for aquatic animals this may be a positive increment and life may be eternal; for terrestrial animals the length of life depends on the nearness to equality of profit and loss. An annual increment, however small, will eventually result in death from gigantism: it is not improbable that this has been, and possibly is now, the form of death in some quadrupeds. A negative annual increment, however, determines a date at which all capital resources will disappear. We die, therefore, as an alternative to becoming giants.

From the statements made in this brief summary it will be seen that evidences of animal evolution and of animal relationship may be secured from a variety of lines of physiological inquiry. These evidences seem as worthy of credence as those coming from paleontology, comparative anatomy or embryology. There are doubtless other similar lines of inquiry which have a bearing upon the general problem, and there can be no question as to the need for much further knowledge of the facts along the lines which have been mentioned.

PHOTOELECTRICITY[1]

By Sir WILLIAM BRAGG, K.B.E., D.Sc., F.R.S., M.R.I.

FULLERIAN PROFESSOR OF CHEMISTRY, ROYAL INSTITUTION OF GREAT BRITAIN

THE relations between light and electricity are of unending interest. More than fifty years ago the experiments of Faraday and the calculations of Maxwell culminated in the splendid electromagnetic theory of light, on which subsequent research has built largely and firmly.

Even in the early days of the theory there was known to exist a peculiar and special relation to which the name of photoelectricity was given. The theory gave no ready explanation of it. Light falling upon a metal plate could cause the plate to become positively charged; ultra-violet behaved better in this respect than visible light. When subsequently the electron was recognized and defined, it became clear that the photoelectric effect could be explained as due to an emission of electrons from the metal under the influence of the light, and various suggestions were offered as to the nature of the mechanism. It was clear that the absorption of energy from the electromagnetic waves of light was replaced by the energy of electrons in motion, though at that time there was no obvious relation between the quantities of energy in the two forms. As time went on it was realized that this particular transformation was not an isolated effect; it was but an instance of one of the most important and widespread processes of physics. It was to be observed not only in the case of light but of X-rays and γ-rays also; and indeed in their case it was infinitely plainer and more accessible to experiment. But it also became continually clearer that the process was not to be explained in any simple fashion, if at all, by the original electromagnetic theory of light, or by any natural development of that theory.

At the same time a number of other physical phenomena, and especially the relation between the quality of the radiation from a hot body, and the temperature of that body, showed also that the older theories were unable to account for the facts. They could be accounted for by supposing that heat could be radiated or absorbed only in parcels of definite size, no fractions being allowed. If such an idea might be reconciled with the undulatory theory, *i.e.*, of electromagnetic waves, at least it was not contained therein. This was the beginning of the quantum period.

In 1905 Einstein published a pioneer paper in the *Annalen der Physik* in which the quantum was given an identity even more definite than that which Planck had assigned to it in his studies on heat radiation. Light was to be regarded not as a uniform train of spherical waves but as a flight of "quanta," corpuscles of some form to be better known on closer acquaintance. By reverting to a corpuscular theory of light he was able to connect the new facts, which were in such apparent discord with the undulatory theory. In doing so he, of course, shut his eyes for the moment to the marvelous and most successful development of the latter theory to the explanation of such phenomena as reflection, refraction and diffraction. He would simply find a new theory to connect the new facts; this done, the new and old theories could be brought

[1] Address before the Royal Institution of Great Britain.

together in the hope of welding them together. As he announced in the title of his paper, he was going to take the heuristic point of view.

Since 1905 new discoveries of first-class importance have been made, but still there is no simple answer to the old question. The most recent and, so it is said, the most successful solution is given by the hypothesis of so-called wave-mechanics, due largely to M. L. de Broglie and Dr. E. Schrödinger. It is now the subject of eager discussion in mathematical and physical circles.

The managers of the Royal Institution have invited Dr. Schrödinger to give a short course of lectures on wave-mechanics at the Royal Institution, and have been gratified by the acceptance of their invitation. It has been arranged that the lectures shall be given on March 5, 7, 12 and 14. Also Professor Whittaker, of Edinburgh, has accepted an invitation to give the Friday evening discourse on March 16, on which occasion he will try to summarize for the benefit of our members the features of the new position.

My discourse this evening is meant to be of a preparatory nature. I would like to set out the observed facts for which it is so difficult to find a common explanation, so far as it is possible to do so in the short time at my disposal. I can not, of course, tell the whole story; I can only describe a few of the most important details of it.

Einstein begins his 1905 paper by pointing out, as a curious fact, that matter is now looked on as a collection of discrete particles, while light, which resembles matter in being one of the great phenomena, is treated as a continuous distribution in the space over which it passes; and he suggests that it would be well to consider a discrete view of light also. He then enumerates certain experimental results which would be in obvious agreement with the new theory, though not with the old. Most of them are beyond our capacity to consider in the short hour of this discourse; but two of them may well be considered by us as amply sufficient to illustrate our argument and easily demonstrable even on the lecture table.

The first of them is summed up in what is called Stokes's Law of fluorescence. When light falls upon a fluorescent substance the fluorescent light evoked is always of longer wave-lengths than the exciting light; in other words, its frequency is less. Now, if a corpuscular theory of light is to be adopted, wave motion of a given frequency must be replaced by some characteristic of the corpuscle; and it appears that the two, and only two, characteristics of a wave motion, namely, frequency and intensity, are to be replaced respectively by individual energy and numbers of corpuscles. This has to be done in order to explain both the results we are considering and a number that we are not. On the corpuscular theory a beam of violet light is a flight of corpuscles each having a certain energy which is proportional to the frequency of the light. A beam of green light is a flight of corpuscles each having a certain energy less than the other, because the frequency is less. It is easy to imagine that the flight of more energetic corpuscles may be degenerated by impact with the body into a flight of less energetic corpuscles. But it is very difficult to see how undulations of one wave-length can on meeting material substances be converted into undulations of a different wave-length.

A still more striking argument is found in the photoelectric effect itself. Lenard had shown three years before that when the electrons came out of the solid body under the influence of the light their individual energy did not depend upon the intensity of the light, but upon its frequency; the intensity affected only their number. This was an extra-

ordinary result. It might have been thought that the more energetic or violent the waves of light which caused the emission of electrons, the greater the velocity with which the electrons would start on their way. And as to the influence of frequency, it would be difficult to say how it would go; though one would not readily expect it to be the sole arbiter of the velocity. But if light was corpuscular the process, though still unexplained in detail, ceased to look so strange. Each corpuscle acting independently would cause the emission of an electron. The intensity of the beam of light would depend on the number of corpuscles it contained, and their impact on the body would cause a proportionately large emission of electrons, making the photoelectric effect. And light of high frequency would on the corpuscular view consist of swiftly moving corpuscles, which, having large energy, would cause the emission of relatively swift electrons. The whole phenomenon, by its character and definiteness, spoke entirely for the corpuscular theory. Einstein explains the point perfectly clearly in his famous paper of 1905, and suggests that, if he is right, far more careful quantitative observations would be justified, as they would give an authoritative verdict on the validity of the theory which he proposed. He suggests that workers might bear his views in mind when proceeding with their experiments.

Einstein's theory must have been discussed exhaustively; but, so far as I know, no allusion to it, or criticism, is to be found in the principal journals of physics for some years afterwards. In fact, it was not until seven years later that Richardson and K. T. Compton carried out the careful measurements which Einstein suggested.

The results were in absolute accordance with the exact rules which he had supposed would govern the photoelectric effect, having based them on the less well-defined information which was available when he first wrote.

I must now be permitted to describe some experiments which I carried out in Australia twenty years ago in conjunction with several helpers, in particular R. Kleeman and J. P. V. Madsen. I had been working out certain laws which governed the passage through matter of the X-rays emitted by radium; and I had tried to carry over the information so obtained to an investigation of the behavior of the β- and γ-rays. Now when γ-rays fall upon a substance they excite β-rays, which are electrons in very swift motion. In fact, the analogy with the photoelectric effect is exact, for the rays as we now know are a form of light of very high frequency. The characteristic features of the photoelectric effect appear here also and greatly emphasized. The swift β-rays are far easier to detect and to examine than the electrons set in motion by light. The parallelism was not then so obvious as it is now, and for my own part I could not then believe in its existence. Our experiments fitted in perfectly with a corpuscular hypothesis of the nature of the γ-rays; and I supposed that the undulatory theory of light was unshakable. I should, of course, have thought otherwise if I had been aware of Einstein's paper, to which I have already referred; but it is easy to miss a single reference when one is in a very isolated laboratory, and, as I said before, there are few if any allusions to the paper in the current literature of the years immediately following its appearance.

Our experiments in 1907 and 1908, coupled with others to which we were able to refer, led us to the following conclusions:

(1) When β-rays or γ-rays were incident on matter the energy of any resulting secondary radiations of any kind, β or γ, came from the rays. There was no

"induced" radioactivity; no case of the energy of an atom being tapped. The adoption of this hypothesis simplified all further considerations of the phenomena.

(2) The so-called hard or very penetrating γ-rays produced swift and penetrating β-rays; soft γ-rays produced slow β-rays.

(3) The penetrating power or quality of the β-rays, produced by the action of γ-rays, depended only on the quality of the γ-rays, not upon the intensity of the γ-rays nor upon the nature of the substance in which the transformation of energy took place; it was practically the same as that of the β-rays issuing from the radium itself.

(4) The β-rays produced in any substance by the action of the γ-rays moved at the outset in the original direction of the γ-radiation.

The last statement is capable of simple demonstration in the lecture room. The necessary apparatus is shown in the figure, which is taken from a paper by Madsen and myself. The radium is buried in a mass of lead, at the foot of a conical pit. Both β- and γ-rays issue from the mouth of the cone, but the former are turned aside by a strong magnet. The γ-rays pass on alone into an ionization chamber. The beam of γ-rays is not quite free of β-rays because the latter are aroused even in the air through which the γ-rays pass on their way to the chamber, but the magnet has removed most of them. If now a carbon plate be placed in the path of the γ-rays as they enter the chamber there is a large increase in the ionization current; the γ-rays as they pass through the block on their way generate β-rays, which cause the observed effect. But if the carbon plate be placed on the far side of the chamber so that the γ-rays strike it on the way out, there is a relatively small increase in the current. Yet the rays must have generated β-rays to very nearly the same amount in both positions of the plate; and the dissymmetry between the intensities of the "emergence and incidence" β-rays (the one is ten times that of the other) tells us that the β-rays are largely thrown forward as they are produced. In fact, from what is otherwise known of the behavior of β-rays on their way through matter, we might suppose that the β-rays were thrown forward exactly in the line of the γ-rays, for the substance of the carbon screen would turn back a certain proportion of the rays, and the incidence radiation could be accounted for in this way. Nevertheless, we know now, from more accurate work which we shall presently consider, the β-rays are not so closely tied down to the forward movement, and when the γ-rays are soft and the β-rays relatively slow the difference between emergence and incidence is less marked. The experimental difference is also much less when the carbon plate is replaced by screens of higher atomic weight.

Thus again we have those characteristics which led Einstein to suggest a corpuscular theory of light in order to account for them when manifested in the photoelectric effect. Here they are displayed in an immensely enhanced degree. Consider the γ-ray as a spherical wave weakening as it spreads away from its source. It arrives at a certain atom; a β-ray springs out of the atom with an energy which is just the same, no matter how intense are the γ-rays, or how the intensity has faded with distance. Moreover, it possesses a forward momentum which could not possibly, by millions of times, be given to it by the wave, although a wave can impart a certain momentum to an encountered obstacle.

These questions of energy and momentum are even more obviously displayed in the case of the X-rays and the electrons which are concerned both in their production and their absorption. In the X-ray bulb the electron is driven

with a certain speed against the anticathode, the X-ray which is thereby excited passes away and, falling on some substance, it may be far or near, sets in motion an electron which has a speed comparable with, sometimes nearly equal to, that of the original. Here again is the same kind of transformation of energy, which is simply pictured as carried, unchanging on its way, either by the β electron or the corpuscle of the γ-ray.

I may say, I think, that in these experiments we were, though unwittingly, carrying out Einstein's suggestion that the corpuscular hypothesis deserved careful exploration; and the results were in entire agreement with his hypothesis. It was true, however, that I thought of the X-ray and γ-ray problems as distinct from that of light; and I ventured prematurely to give form to the corpuscle as a neutron, an electron compensated as to its charge by the addition of a neutralizing amount of positive.

In 1910 and 1911 C. T. R. Wilson published accounts of his experiments with his fog chamber. These rendered obvious to the eye those tracks of the various rays through a gas which we had endeavored to map out by more indirect means, and entirely confirmed the conclusions that had been reached. I may perhaps be allowed to illustrate this in the special case of the α-rays, though they do not fall within the limits of our subject. In Fig. 1 is shown a set of tracks of α-rays drawn so as to be in accord in the first place with the work done in Adelaide; and also to agree with the more recent experiments on their scattering performed by Rutherford and Geiger. Fig. 2 is from a photograph of one of the well-known early achievements of Wilson. It may be a matter of interest that on a certain occasion in the Cavendish Laboratory at Cambridge we showed them to each other for the first time.

Wilson's photographs of the tracks of X-rays, β-rays and cathode rays, placed the argument on a different plane; and their beautiful detail opened up the way to quantitative measurements which had seemed impossible. It was now obvious

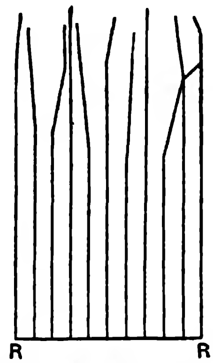


FIG. 1. SUGGESTED FORMS OF THE PATHS OF α PARTICLES PROJECTED UPWARDS FROM RADIUM AT R R.

FIG. 2. FROM PHOTOGRAPH OF α-RAY TRACKS BY C. T. R. WILSON.

Courtesy of Macmillan & Co., Ltd.

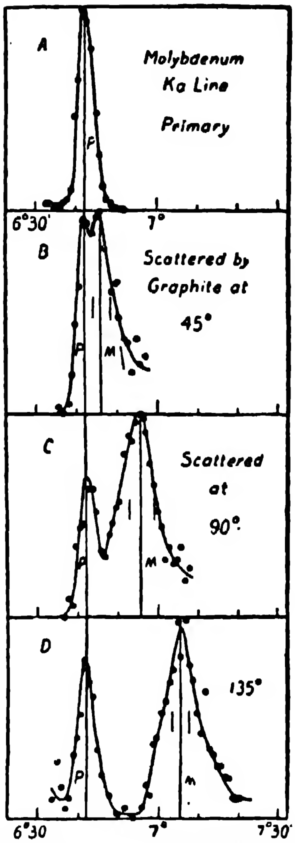
to the eye that X-rays and γ-rays did not of themselves ionize a gas, but set in motion electrons which did so. The lengths of the tracks of these electrons in a gas could be measured, and their initial

velocities be calculated therefrom; their directions of ejection could also be observed. All fitted in perfectly with the quantum theory of the X- and γ-rays, even when refinements could now be studied, as, for example, the differences in velocities of ejection which were to be expected on Bohr's theory of stationary state.

In 1913 the discovery of the diffraction of X-rays by the crystal opened up a new point of view, and once more changed, or rather enlarged, the aspect of the question. It now appeared that X-rays and γ-rays in these effects behaved like long trains of spreading waves, and no clear picture of what happened could be obtained in any other way. In this matter the corpuscular theory was at sea. Even the old single-pulse theory was in no better case, because it did not provide the regular succession of similar waves which was required to account for the crystal effect. The new discovery consolidated the position, linking together light, X-rays and γ-rays as one phenomenon; if they were regarded from the point of view of the undulatory theory they were all waves which differed only in frequency. If any other point of view was taken, that of a corpuscular theory for example, the equivalence must be expressed in some equally effective fashion. On the other hand, the simplification emphasized the difficulties of the position, since it left no escape from the necessity of finding a theory which could with equal ease and effectiveness express itself in terms either of waves or of corpuscular projectiles. Whether or no this has yet been done by any of the theories now in being is indeed the question of the day; our judgment will, I hope, be assisted by the lectures that are to follow.

Meanwhile matters have by no means remained stationary since the powers of X-ray and crystal analysis have been put into our hands. With the aid of the X-ray spectrometer we can measure with extreme accuracy the wave-lengths and frequencies of X-rays. When X-rays are incident upon a substance they are to some extent scattered as such, just as a ray of light is scattered in passing through a dusty atmosphere. This is apart from the photoelectric effect, namely the production of swift-moving electrons at the expense of the energy of part of some of the incident rays. The X-rays are scattered by the atoms and electrons; the light being of coarser wave-lengths is scattered by the coarser particles of dust. Now when γ-rays, which are very fine X-rays, are scattered it has often been remarked that the scattered rays are somewhat softer than the originals. A. H. Compton used the spectrometer to examine if possible this softening, if X-rays could show it. They not only did so, but the experiments showed also a real change of wave-length varying according to circumstances, and obeying simple rules. It appeared, in fact, that there was a definite small change in wave-length, which depended on the angle of scattering, but not on the original wave-length nor on the nature of the scattering material. Figs. 3 and 4, taken from Compton's new book "X-Rays and Electrons,"[2] show the effect very clearly. They represent the results of the spectrometer observations; in each curve one hump is due to rays that have not been altered by scattering, and have preserved the same frequency as the original beam. A second hump is the evidence of the "modified" scattering; the relative amounts of the two vary with the scattering substance. Every material returns something of both kinds; but the lighter the atom the more intense is the modified in comparison with the unmodi-

[2] A. H. Compton, "X-Rays and Electrons." New York, D. Van Nostrand Co., 1926.



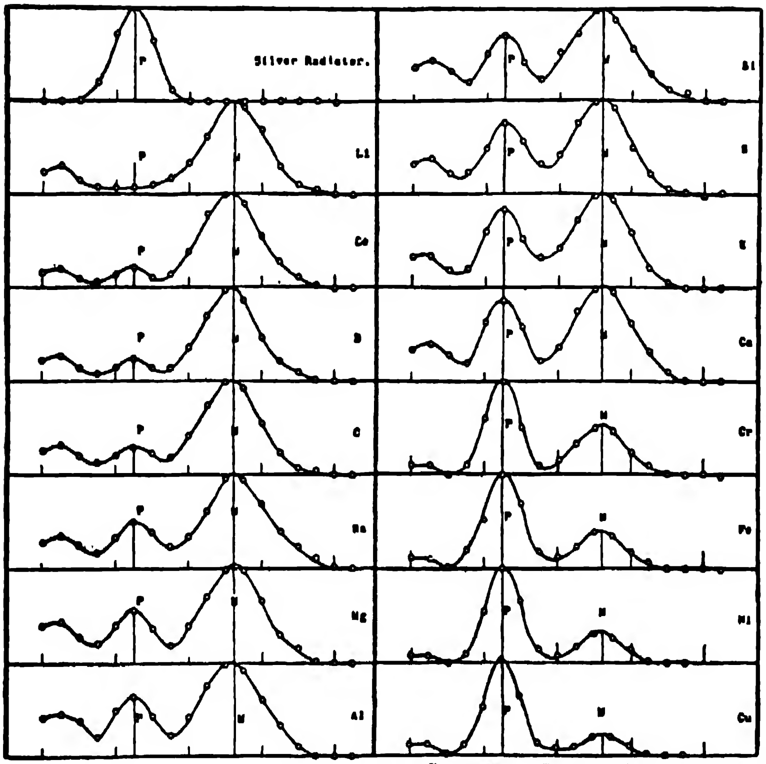
Courtesy of D. Van Nostrand Company, Inc.

FIG. 3. ABSCISSAE REPRESENT ANGLE OF SCATTERING AND ORDINATES REPRESENTING INTENSITY. THE HUMP ON THE LEFT OF EACH FIGURE REPRESENTS THE INTENSITY OF THE SCATTERED RADIATION, WHICH HAS THE SAME WAVE-LENGTH AS THE PRIMARY BEAM. THE HUMP ON THE RIGHT MARKED M REPRESENTS THE INTENSITY OF THE MODIFIED PORTION OF THE SCATTERED RADIATION. THIS FIGURE SHOWS HOW THE EFFECT DEPENDS ON THE ANGLE OF SCATTERING.

fied; at the same time, as already said, the change of wave-length is constant from substance to substance. The phenomenon is a little like that of fluorescence, but the likeness is only on the surface. But this is true of both, that the undulatory theory does not suggest a simple explanation in either case. I ought to say that Professor Raman, of Calcutta, has just announced in *Nature* that he is able to explain the Compton effect on classical lines, and promises to give his new theory in full.

On the other hand, the corpuscular theory gives at once an explanation which is relatively simple, and allows quantitative deductions to be made which are in entire agreement with the facts. If a corpuscle or "photon," to use the term which has lately been suggested, comes into collision with an electron, as it can do in traversing any material, it is possible to work out the consequences as if for an impact between two billiard balls, assuming only that both photon and electron have momentum and energy, the quantities being reckoned according to rules already established. The result is that the photon goes off with somewhat diminished energy; it has lost "frequency," and the calculated loss is exactly that which is shown in Fig. 3 as the result of experiment. Moreover, the electron ought to start off with a certain amount of energy, and when Wilson's photographs are examined the predicted tracks are found on them. Thus the spectrometer, which is based on an undulatory theory of X-rays, has established facts which are in accord with the corpuscular theory.

When we see in this way that radiation, which has always been thought of as undulatory, can on occasion display corpuscular properties, we are prompted to ask whether moving electrons—β-rays, cathode rays, and so on—which we have always considered as corpuscular, may not behave sometimes like waves? The answer appears to be in the affirmative. In America Davisson and Germor have recently described most remarkable experiments in which moving electrons are reflected by crystals in a manner bearing an obvious, though diffuse, resemblance to the now well-known reflection of X-rays, and the latter is always ex-



Courtesy of D. Van Nostrand Company, Inc.

FIG. 4. THE SCATTERING SUBSTANCE IS MODIFIED, AND IT IS TO BE OBSERVED THAT THE LESS THE ATOMIC WEIGHT OF THIS SUBSTANCE THE GREATER IS THE RELATIVE MAGNITUDE OF THE MODIFIED PORTION.

plained on the basis of an undulatory theory. More recently still, Professor G. P. Thomson, of Aberdeen University, has shown that when electrons are shot through a very thin film of metal, halos are formed upon a photographic plate on the other side of the metal, which may be explained qualitatively and quantitatively if the electrons act as waves in passing through the minute crystalline particles of the metal film. Professor Thomson has promised, I am glad to say, to give us an account of this work in a Friday evening discourse after Easter, and this will follow naturally on the lectures by Dr. Schrödinger and Professor Whittaker.

I hope that this brief sketch of the present position will give some idea of its extraordinary and fascinating difficulties. Perhaps the details of the picture are sorting themselves out, and we shall see before long where we have failed to see some important point which was required for the complete resolution. When the picture is finally clear there will no doubt be atoms in it, electrons, wave motions, energies, momenta, and so on. But have we got them all rightly joined? Perhaps wave motion belongs to more than the photon, or to something else than the photon? We can only wait.

LOGIC OF GRAVITATION

By Dr. HENRY LANZ

STANFORD UNIVERSITY, CALIFORNIA

In the opening chapter of "An Introduction to Celestial Mechanics" Professor F. R. Moulton expresses a regret that owing to the difficulty and complexity of metaphysical speculations science is not in a position to enter into the discussion of questions pertaining to the "origin" of the laws and principles involved. "It is not to be understood," he adds, "that such investigations are not of value . . . In order to obtain a complete understanding of the character of the conclusions it would be necessary to make a philosophical discussion of the reality of the elements and of the origin and character of the principles and laws." This is a vast design involving the whole body of logic. In partial fulfilment of it the present paper is conceived.

Modality of Gravitation

Every law of nature is an assemblage of logical elements in a specific correlation with each other. Among various forms of interrelation of those elements there is one which the logicians of the old school were in the habit of calling modality. Modality is a logical category that indicates the degree of certainty associated with a given judgment. A judgment — and every law of nature is a judgment—may be pronounced problematically as mere conjecture, or stated empirically as a fact, or on the basis of certain assumptions established as a necessity. Thus modality is commonly regarded as having three forms: hypothesis, facticity and necessity. The only form of necessity recognized by science is mathematical necessity.

Now we are in position to formulate our problem more specifically. From the vast terrain of inquiry suggested by Professor Moulton we select a small, but highly representative and instructive segment. We limit our task at present to the logical analysis of the law of gravitation, and more specifically to the analysis of modality of that law in the form in which it was originally formulated by Newton.

Is the law of gravitation a mere hypothesis invented to suit certain facts obtained by observation? Or does it possess a certain degree of mathematical necessity which can be formulated apart from and prior to any astronomical observation or physical experiment? If it does, in how far is it mathematically "necessary" and in how far does it depend on "facts"? It is commonly believed that the law of gravitation is a hypothesis with a very high degree of verification by facts. Is this current interpretation of the modality of the law correct? "Hypothesis," we read in an authoritative treatise on logic,[1] "is a name that may be applied to any conception by which the mind establishes relations between data of testimony . . . so long as that conception is one among alternative possibilities, and is not referred to reality as a fact." Is the law of gravitation "referred to reality as a fact" or does it allow "alternative possibilities"? We shall begin our investigation with the law of areas.

Law of Areas

On the assumption of central acceleration is it possible for a body not to describe equal areas in equal times? Let us briefly recapitulate Newton's argu-

[1] B. Bosanquet, "Logic," 2, 155.

ment on this important point. Suppose a body is subject to a central force, whatever its nature may be. Let us regard the action of the force as represented by a series of infinitesimal blows or pushes. Suppose that at the time instant t_0 the body moves in the direction of the line AC (Fig. 1), and that upon arriving at B at the end of an infinitesimal interval of time t_0t_1 it is acted upon by an instantaneous force acting along the line OB. During the next increment of time $t_1t_2 = t_0t_1$ under the effect of two velocities the body will be sent to the point E, CE = BD being the velocity acquired at the end of the preceding interval of time. The triangles OEB and OCB having the base OB and equal altitudes EM and CL have equal areas. For similar reason the area of the triangle BOC is equal to that of BOA. Therefore $\triangle EOB = \triangle BOA$.

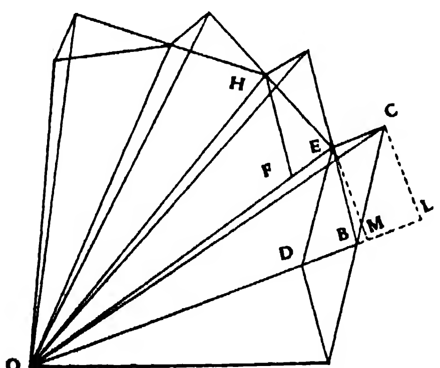


FIG. 1

If the process be repeated, during the next equal interval of time the lines OE and OH joining O to the positions occupied by the body at the instants t_2, t_3 will form triangles of equal areas without regard to whether the lines EF and BD are equal or not, *i.e.*, whether the acceleration is constant or not. Since the duration of our time increments may be diminished indefinitely and since in any given interval of time equal number of equal triangles will always be described by the line joining the body to the center O, by the process of integration we are entitled to conclude that no matter how the body moves around O the areas which it describes by radii drawn to an immovable center lie in the same immovable plane and are proportional to the times in which they are described.[2]

There is no alternative in this argument. On the assumption of central acceleration no physical body can move in any other way. The equality of areas traversed by the radius vector in equal times is, therefore, not a hypothesis, but a mathematical fact deduced from a given assumption. Whether the assumption is "true" or not does not in the least affect the value of the deduction. In fact, our deduction does not show that there is any physical body in the universe which moves exclusively under the effect of central acceleration. It only shows that if there were any such body, the law of areas would be invariably true of its motion. No experimental evidence would add anything to the conclusiveness of the argument. Newton makes no reference to Kepler's observational data; they do not appear among the premises of his argument. In fact, his intention is to explain those observational data by reference to the law, and not the latter by reference to the observed facts. If Newton's assumption is true it follows that Kepler could not possibly observe Mars performing any other movements than those which he actually observed.

This, however, does not in the least diminish the value of observation. Mathematical analysis never gives us any clue as to reality of the objects discussed. It only shows that if such and such a proposition is true of anything, some other proposition must be true of that thing. If there is in nature such

[2] Newton, "Principia mathematica philosophiae naturalis," Book 1, Prop. 1.

a thing as a Euclidian triangle, the sum of its angles must be equal to 180°. If there is any body that moves under the effect of a central force, its radius vector must describe equal areas in equal times. Newton proves that the converse is also true (B. 1, Prop. 2), *i.e.*, if there is a body that follows the law of areas, it must be moving under the effect of a central force. Yet the mathematical analysis can not prove that any such body exists. Here the observation comes in. Kepler observed that Mars does actually move in such a way that the radius vector joining it to the sun covers equal areas in equal times. The conclusion is that the planet has a central acceleration towards the sun.

Galilei's Achievements

It is furthermore not difficult to show that under the assumption of a constant central acceleration all Galilei's formulae for falling bodies follow mathematically from that single assumption. For, since the acceleration is constant, we have

$$\frac{d^2s}{dt^2} = k.$$

After two successive integrations it becomes:

$$s = f(t) = {}^1/_2kt^2 + C,$$

i.e., acceleration can be constant only on the condition that the original function (the space traversed) is proportional to the square of the time, which is the basis of all Galilei's deductions.

Next to Kepler's three laws of planetary motion, Galilei's law of the falling bodies constitutes another historical premise of Newton's work. We see again that this premise involves no hypothetical elements. It is not a happy guess that should be first verified by a laboratory experiment. It is mathematically necessary. If we assume that heavy bodies fall under the effect of a force that remains constant, they can not possibly fall according to any other law —not because we observe them in that condition, but because it is mathematically impossible. To say that a body moves under the effect of a constant force is the same as to say that the space traversed by it is proportional to the square of the time.

Newton's Law of Gravitation

We have seen that Galilei's laws of falling bodies follow mathematically from the assumption of a constant gravitational force. It is natural to assume that the force remains constant on the surface of the earth as long as we believe that earth is a perfect sphere. But what will happen to the force as we move away from the center of gravity? Will the force vary with the distance? And if it will, according to what law? That was the problem that Newton faced.

And here we clearly perceive at once that the concept of central force alone is not sufficient to derive the law of gravitation. It does not give us any clue as to how the intensity of force will change with respect to the distance. In each particular case the nature of the path depends on the law of the force. If we know that the body moves in a spiral, then—assuming that it moves under the effect of a central force—we can analytically find that the intensity of that force changes in the reverse proportion to the cube of the distance (B. 1, Prop. 9). If we know that the body moves in an ellipse, then—assuming that it moves under the effect of a force directed toward the *center* of the ellipse—we shall find that the force changes *directly* as the distance. Suppose that we never find such conditions in nature. That would have no effect upon the mathematical validity of our results. In fact we never find those conditions fulfilled, at least not in celestial mechanics; the controlling body of a gravitational system is never located in the center of any elliptical orbit described by any of its satellites. It is always found to be located in the *focus* of the ellipse.

Thus it is impossible to derive the law of gravitation mathematically from the assumption of central force, as it was possible with regard to the law of areas. In this latter case we needed no support from any observation whatsoever. Every moving body controlled by a central force must comply with the law of areas, no matter what the law of the force may be. In other words, it is independent of the nature of acceleration. But the law of gravitation is a specific law. We can not derive it from the generic concept of central force. There are many other laws mathematically possible. Here is, therefore, a point where observation substantially affects our celestial mechanics. In order that we could find the law of force, the path of a body moving under the effect of that force must be given. And when it is given, the law of force follows mathematically from it. It is, therefore, not a matter of mathematical necessity, but merely a matter of fact that the force of gravity is inversely proportional to the square of the distance.

Therefore, the assumption of central force as applied to the observed paths of the celestial bodies is logically sufficient to produce the law of gravitation. No further hypothesis as to the nature of the force is needed. The assumption of central force is the only hypothesis that Newton makes. And with it stands or falls his whole fabric. If we assume that planets are driven by forces—which is by no means self-evident, as they may move in similarly curved lines owing to the nature of the time-space—if we assume that they are driven by forces in a Euclidian space, then the form of their orbits mathematically determines the law of the force.

Thus we see that the common interpretation of the law of gravitation as a hypothesis that "admirably fits the facts" is logically incorrect. It does not merely fit the facts of observation, but it is nothing else than the mathematical expression of those facts. It is not a guess that for some unknown reason is found to be universally correct. It is also erroneously called a deduction from observations. For Newton made his deductions independently of observations and concluded that wherever the conditions of his analysis are fulfilled in experience the results must also hold true. "In mathematics," he writes, "we are to investigate the quantities of forces, with their proportions consequent upon any conditions supposed; then, when we enter upon physics, we compare those proportions with the phenomena of nature, that we may know what conditions of those forces answer to several kinds of attractive bodies. And this preparation being made, we argue more safely concerning the physical species, causes and proportions of the forces."[8]

To say that intensity of gravitational force is inversely proportional to the square of the distance is merely another way of saying that celestial bodies in the immediate neighborhood of each other move with respect to each other in conic sections. With such paths given by observation there could not be any alternative as to the law of the force controlling them. Planets could not possibly move in elliptical orbits, and at the same time obey some other law. If we had suddenly discovered a body that moved around the sun on a spiral, we would be obliged to conclude, not that the law of gravitation is invalid, but that the sun acts with regard to that body, not as a gravitational center, but as a center of some unknown force whose intensity varies as the cube of the distance. But there again could be no alternative. The modality of the law could not be interpreted as a hypothesis.

Einstein's Law

Yet it may be objected that Einstein's law presents an alternative. The solution of Einstein's equations of the gravi-

[8] "Principia," Book 1, Prop. 69, Scholium.

tational field leads to the conclusion that in the neighborhood of a material particle our space-time is non-Euclidian.[4] That shows that our physical space-time is not everywhere flat, but is curved within electromagnetic and gravitational fields. In such space particles will move in curved lines independently of any attractive forces. That is to say, the assumption of space-time curvature is sufficient to account for any material particle's deviation from Euclidian straight line. Moving solely under the effect of inertia every material body in the neighborhood of another material body will follow a curved path. The curvature in this case, however, will not exactly coincide with that which is prescribed by Newton's law. The deviation will be extremely small, yet the more appreciable the nearer we come to the center. Such deviation was actually observed in the motion of Mercury, whose perihelion was found constantly displaced in a manner unaccountable on the basis of Newton's law.

Now, does it prove that Newton's law of universal gravitation is no longer valid? But what does it epistemologically mean, "no longer valid"? If it means that conditions formerly assumed to be real are no longer observed to be real, then the law is not strictly valid, even though the discrepancy is very small. Yet we can always hope to account for the disagreement considering a possibility of some disturbing factor of which we are at present unaware. The discrepancy in the case of Mercury is in fact so small and so unique that to declare the whole system invalid just on its account would be quite premature. If, on the other hand, "not valid" means mathematically or logically inconsistent, then, of course, Newton's law is, and always will be, just as secure as it ever was before. No amount of observational evidence or advanced mathematical analysis can destroy its validity in this sense. For as long as we remain within the sphere of Newton's fundamental assumptions, *i.e.*, as long as we believe in force, his deductions are inviolable.

And yet there is a sense in which Newton's law may be regarded as no longer valid. Euclid's assumptions are neither more nor less reasonable than those of Riemann or Lobachefsky. They are purely mathematical postulates which can be independently and arbitrarily pursued till their remotest consequences are reached. But Newton's assumptions are not purely mathematical. They involve a factor which determines acceleration, and is not itself identical with acceleration. "If any force," Newton says, "generates a motion, a double force will generate double the motion, a triple force triple the motion." This is evidently an assumption that can never be verified by observation, for force is inaccessible for observation except through the motion which is generated or determined by it. If force increased in geometrical progression, while the quantity of motion gained only arithmetically, no one would be able to discover it. The truth of the assumption, therefore, lies solely in our inability to verify it. Such force is a mere farce. It is a remnant of the animistic, theological thinking.[5]

[4] A. S. Eddington, "Space, Time and Gravitation," p. 97.

[5] A highly satirical caricature on the nature of this assumption we find in Eddington's "Space, Time and Gravitation." He presents the situation in form of a fairy tale: "A race of flat-fish once lived in an ocean in which there were only two dimensions. It was noticed that in general fishes swam in straight lines unless there was something obviously interfering with their free courses. This seemed a very natural behavior. But there was a certain region where all the fish seemed to be bewitched. . . . By-and-by a theory was proposed; it was said that the fishes were attracted towards a particularly large fish—a sun-fish—which was lying asleep in the middle of the region; and that was what caused the deviation of their paths. The theory might not have sounded particularly plausible at first. . . . Some fish

Einstein, following Minkowski, instead of assuming a force as a factor generating acceleration of gravity, proposed to assume a different geometry in the neighborhood of material bodies. On this assumption gravitational acceleration becomes indistinguishable from mere inertia. A planet, for instance, obeying no other law than that of inertia, acquires central acceleration towards the sun, not because the latter attracts it in some mysterious way through the distance, but simply and solely because the nature of space-time makes it appear to be moving under the effect of an attractive force directed towards the origin. Thus was destroyed the only hypothesis that Newton had ever made. Modality of gravitation was proven to be free from any hypothetical elements. In a letter to Cotes Newton writes: "Whatever is not deduced from the phenomena is to be called hypothesis; and hypotheses, whether metaphysical or physical, . . . have no place in experimental philosophy. In this philosophy, particular propositions are inferred from the phenomena, and afterward rendered general by induction." Of all the logical elements that constituted the law of gravitation force was the only one that was "not deduced from the phenomena." And it is precisely this element that is now discarded.

HYPON—A HYPOTHETICAL ELEMENT AND A POSSIBLE SOURCE OF STELLAR ENERGY

By W. S. ANDREWS

THE GENERAL ELECTRIC COMPANY

THE source of the energy that is continuously radiated into space chiefly in the form of heat and light by our sun and other stars is an unsettled problem although many ingenious theories have been devised to account for it. The evolution of temporary stars or "novas" is also still enshrouded in mystery. It was formerly believed that a nova was a cosmic conflagration caused by the collision of two heavenly bodies, but modern study has ascribed its appearance to the actual explosion of a star from within itself, like a gigantic bombshell. A few facts—and fancies—relating to these matters are here presented to the reader.

It is well known that the atomic numbers of six gases—helium 2, neon 10, argon 18, krypton 36, xenon 54 and radon 86—agree with the first six terms of the following simple number series: $2(1^2 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2 + 4^2 + \ldots)$. That is to say:

$2(1^2) = 2$, helium's number
$2(1^2 + 2^2) = 10$, neon's number
$2(1^2 + 2^2 + 2^2) = 18$, argon's number
$2(1^2 + 2^2 + 2^2 + 3^2) = 36$, krypton's number
$2(1^2 + 2^2 + 2^2 + 3^2 + 3^2) = 54$, xenon's number
$2(1^2 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2) = 86$, radon's number

This remarkable agreement in numbers, up to and including the sixth term of the number series, invites attention to the seventh term, which is 118 $[2(1^2 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2 + 4^2) = 118]$. There are, however, only ninety-two known chemical elements, and uranium being the heaviest is atomic number 92. It is, therefore, plain that 118 can not be counted as an atomic number unless, indeed, twenty-six new and hypothetical elements, all heavier than uranium, are arbitrarily added to the regular stand-

grumbled that they did not see how there could be such an influence at a distance; but it was generally agreed that the influence was communicated through the ocean and might be better understood when more was known about the nature of water."

ard list. This idea may naturally be deemed too wild for serious consideration, but nevertheless it is proposed to offer some speculations on the subject.

Since radio-activity was discovered at the end of the last century, it has been conceived that just as lead is known to be the end product of radium, so also may many of our other common and well-known elements be the end products of certain very heavy radio-active substances which existed in the far-off ages of the distant past and which, although they have apparently disappeared from our visible universe, may possibly have survived under conditions favorable for their preservation. It is also possible that these conditions may obtain in the interior regions of our sun and other stars. Having these clear possibilities in view let us return to the hypothetical element number 118, which is at least closely linked to a chain of six well-known gaseous elements by a clear-cut number series as previously shown. Let us name this element "hypon" for future reference, and let us give it, if you please, "a place in the sun."

We have already seen that hypon is radio-active and on account of the great size and complexity of its atoms it is reasonably certain to possess this property in a superlative degree. Its superactivity, however, must be greatly reduced by the tremendous gravitational pressure of its environment. It is highly probable, indeed, that the superactivity of hypon is so well regulated by this pressure that only sufficient energy is liberated to maintain the sun's radiation of heat and light constant and uniform through all the ages. There is evidence, however, of regular cyclic changes in solar radiation which must occur in obedience to certain natural laws and conditions with which we are not at present well acquainted.

If it is allowed that the radio-activity of hypon is influenced by pressure, it follows that as the pressure decreases the activity will increase and at a certain critical minimum point of pressure every atom in the mass of hypon will spontaneously disintegrate and then reform into other atoms of lighter weights and greater stability. These changes will be accompanied by a certain loss of original mass due to a partial dematerialization of the hypon atoms. Dematerialization in this sense means that during the disintegration of the ponderable hypon atoms a part of each atom is transformed into imponderable energy chiefly in the form of heat, this being a common feature in radio-active phenomena. When the disintegration is intermittent and occurs in various individual atoms scattered through the mass, as in a salt of radium, the production of heat energy is insignificant and may serve to raise the temperature of the mass only one or two degrees. In regard to the matter of hypon, however, the conditions and results are entirely different, for here we note the instant disintegration of countless myriads of heavy complex atoms involving a tremendous outburst of heat energy in the very midst of a crowd of light and simple atoms, thus providing all the requirements for a powerful explosive reaction. Briefly stated, hypon can not exist except under the stabilizing influence of great pressure, and if this pressure falls below a certain critical minimum the hypon will instantly explode with intense violence.

With this conception of hypon as our hypothesis we may evolve the following as a bit of cosmic history. "Once upon a time" there was a star which may have been as large as our sun or larger, but it was located so far away from our earth that nobody here had ever seen it.

This star contained a large amount of hypon, which was kept in a condition both safe and serviceable by gravitational pressure, so everything was well with the star and age after age rolled

on serenely until the arrival of a fatal hour when its long and tranquil existence was brought to a sudden and tragic end by a very strange catastrophe.

A series of transient waves of tremendous energy surging through space took a path so near to our star that the latter was terribly shaken so that its internal pressure dropped momentarily below the critical minimum of hypon. The result was instantaneous and too appalling for adequate description, for the mass of hypon detonated and the star, as such, ceased to exist. In its place there was a huge mass of intensely heated gas and vapor in furious chaotic commotion already distended to many times the size of the former star by the force of its explosion and still expanding at such a prodigious rate that in a comparatively short time it had spread out into space in all directions for millions and millions of miles. The eruption of matter and energy from the detonated hypon was vast beyond comprehension, but it had its limits, for its expansion could not go on indefinitely. In due time, therefore, the outward motion became slower and slower, then ceased, and the transcendently immense and brightly shining sphere floated stationary and unchanging in the ether for a considerable period. At length, however, the force of gravitation within and the piercing cold of space without combined to initiate the process of condensation, and the outermost shining clouds began to fall inward and mingle with the underlying mass. Contraction being thus well started, it must surely continue to a natural finish and we may now return to earth.

About a hundred years or more after the occurrence of this celestial cataclysm the first bright beam of its radiant light dawned on our planet, and we saw a pale white star in the sky where no star had ever been seen before. Then, to our wonder and amazement, this star began to brighten, and from week to week, and month to month, it grew still brighter and brighter until it was thought by many to be the brightest star in all the sky, and so it remained for a long time. Then gradually its light began to wane and week after week, and month after month, became weaker and weaker until it could hardly be seen and few people, excepting the astronomers, thought any more about it.

So it was that we watched the gradual development to its maximum brightness and beauty and then the slow decline of this wonderful and mysterious apparition in the sky which was called a nova, and which, if our hypothesis be the truth, was but the manifestation of atomic number 118, the seventh of our number series, hypon!

SCIENTIFIC EXPLORATION
A PHANTASY

By Professor G. F. FERRIS
STANFORD UNIVERSITY

BEHIND a pair of plodding burros that bore his equipment and his meager personal belongings the scientific explorer tramped along through the heat of a tropical afternoon. Beneath his helmet the sweat coursed in furrows through the accumulation of dust on a face that showed strangely pale under the dirt and the bronze of the sun. The fever that had burned within him for days, and against which the few simple remedies that he had been able to carry with

him were of no avail, had sapped his strength, but he held doggedly on. The coast and a port were but a few days away.

The afternoon wore on and still the narrow trail through the crowding jungle revealed no evidence of a human habitation. The sun set and the fleeting tropical dusk was almost gone when a distant cock-crow gave evidence of the presence of a ranch. It was dark when the traveler came finally to the little group of thatch huts at the side of a stream and sent his native boy in to arrange for a bit of supper. Wearily the two stripped the packs from the animals and the boy threw before them such scanty fodder as he had been able to buy.

There came a call from one of the huts that their supper was ready, and the two went up. About a few gourd dishes on the dirt floor, illuminated only by a flaring torch, squatted the head of the household and his numerous brood, all dipping with their fingers into a common dish. The traveler received the courtesy of a crude stool upon which to sit and another that served for a table. Before him, in gourd dishes, were placed the coarse tortillas and the beans that constituted the customary and indeed almost the only food of the country.

It was poor food, the tortillas coarse and unappetizing, the beans tasting as if they were moldy, but the traveler had become inured to such things and above all he had learned to give no thought to the methods by which such food was prepared. With it disposed of there remained nothing to do but to go to bed, even if his illness and weariness had not of themselves demanded such action, for the slender literary resources of his pack were long since exhausted, as were the even more slender conversational possibilities of his native boy. With the people in the huts he could not converse, for their barbaric version of Spanish and his own slight knowledge of the classical form had but little in common.

He stretched his hammock between two trees and turned in. The multifarious sounds of the night—the barking of dogs, the squealing of pigs, the ghastly braying of the burros, the bellowing of bulls, the bawling of calves, the crying of babies, the sound of endless conversation from the huts—beat upon an ear rendered sensitive by illness. In spite of his weariness hours passed before he fell into a dream-troubled travesty of sleep.

About him the air hummed with mosquitoes.

Above the tropical forest sounded the distant drone of an aeroplane motor and the sinking sun flashed upon the plane's wings as it spiraled down to an extensive clearing among the trees upon the shore of a mighty river. The plane came to rest a short distance from a group of neat houses that filled one end of the clearing and as the occupants of the houses emerged the pilot climbed down and turned to assist a woman to alight.

From the approaching group of men and women, attired much after the fashion of the front porch loungers of a country club and one or two of whom carried tennis rackets, a man detached himself and stepped forward to greet the woman. "Welcome, Mrs. Catherton," said he, "to the base camp of the Ultimate Amazon Expedition. I am the director, Dr. Osmand. You will find it a bit rough here, but still I hope you will not consider your stay with us entirely unpleasant. Let me introduce some of my assistants." The group that had remained at a respectful distance came forward. "Mrs. Catherton, my first assistant, Mr. Hampstead—the chief of our radio service, Mr. Ashton—the chief of the bureau of public contact,

Mr. Smith—our chief artist, Miss Alderby—the chief of the photographic bureau, Mr. Wilson—our chief clerk, Miss Peters—the chief of transportation, Mr. Anderson."

He motioned to a white-clad native servant, who had already gathered up the newcomer's bags as they were unloaded from the plane. "Anastasio will show you to your room. We dine at seven."

About the tables of the mess hall, set with snowy napery and gleaming glass, there were grouped at least thirty of the more important members of the expeditionary staff, including those whom Mrs. Catherton had met and a number of other clerks, stenographers and underlings of various sorts. Dr. Osmand entered with Mrs. Catherton and motioned to them to be seated. "It had been my thought," he said, evidently continuing a conversation, "that we should follow the very admirable custom said to have been set by English gentlemen isolated in wild parts of the world and always dine in evening dress. One should never let himself go simply because he is separated from his fellows, and so I have always insisted that the members of my staff should never forget the respect due to themselves as well as to their colleagues. But it is so very hot here that I trust you will pardon us for dressing in white instead of the conventional black."

"It is a very great honor to have you with us, Mrs. Catherton," said the chief of the bureau of public contact, who was seated on her left. "I think every one here has read your books. For myself, I have especially enjoyed your 'Vengeance of the Tropics.' It is perfectly amazing that one who has never been in the tropics can so well describe them and so well understand their influence upon the soul of the white man. With the—er—ah—slight increase in knowledge of local color that you will doubtless obtain from your visit with us I feel sure that your next book will be even more wonderful. We are all looking forward to it and hoping that you will deal gently with us. Dr. Osmand has asked me to see that all available information and every possible resource are placed at your disposal. But we can discuss that later."

As the dinner concluded, the chief addressed the novelist. "We start our radio program at eight-thirty. I know this is short notice for you, but I feel sure you will rise to the occasion and say a few words about your first impressions of our expedition. When that is over we shall have a pre-view of one of the movies that we have been making."

Within the radio broadcasting room the announcer stood before the microphone. "This is the Ultimate Amazon Expedition, sent out by the Greatest Museum on Earth, broadcasting from our station in the heart of the Amazon forest. The famous novelist, Mrs. Catherton, known to all of you, is now visiting with us and she will speak to you."

The woman took her place before the microphone. "My dear friends and public. You who have read my books will be pleased to know that the sponsors of the Ultimate Amazon Expedition have generously permitted me to join this expedition in order that I may gain an even deeper understanding and appreciation of the tropics and that none of the possibilities of the expedition may be overlooked. There have been many scientific expeditions in the past that have literally thrown away the greatest products of their work. True they have brought back scientific specimens to be stored away and forgotten in museums and data to be entombed within scientific volumes that few will ever read. But they have entirely overlooked the human interest of their work. They have entirely ignored its literary possibilities. The world, which really sup-

ports these expeditions, has a right to receive in return something more than dry-as-dust geographical data or descriptions of new kinds of plants and animals. This the sponsors of this expedition thoroughly realize and so I have been asked to join their party in order that these literary possibilities may be fully utilized. It is with some trepidation that I decided to accept their invitation and to join in facing the discomforts and dangers of life in this great wilderness. But then one must be prepared to make some sacrifice . . ."

The weary traveler moaned and turned over restlessly in his hammock.

The broadcasting went on. The chief of the medical division was speaking. "The dangers of disease have been largely overcome. Our food is shipped to us directly, even including milk and butter, by fast planes that are equipped with refrigeration systems. These planes are a part of the efficient system of the Tropic Airways Company. Should you decide to spend your vacation in South America you will find no better medium of travel.

"When it has arrived here at our base camp the food is kept in perfect condition indefinitely by the wonderful refrigeration system installed for us by the Polar-air Company, and we send it out as needed to the outlying camps by hydroplane or by fast motor-boats that are able to traverse the smaller streams. These little boats are powered by Speedo motors, which are fed by Energo synthetic fuel and have never yet failed us in time of need. Our portable base camp buildings are built of Impervo fiber and are screened from the mosquitoes and other insects by that good copper screen made by the Nofly Screen Company . . ."

The traveler stirred again, brushing from his face the mosquitoes that had settled upon it.

Dr. Osmand sat in conference with the chief of his bureau of public relations. "See to it that she gets all the stuff she needs. In addition to her book she is going to write a number of short stories, so dig up some good incidents for her. You might get the Indians to put on a dance for her this evening. The museum has been raising the devil because our publicity stuff has lost its pep and the money for the continuation of the expedition isn't coming in as it should. Run some stronger references to our benefactors into the radio talks. They are paying well for their publicity and they claim they are entitled to lots of it. Maybe it is a bit crude, but you'll have to chance that. Give the Speedo people some sort of a story about how one of their gallant little engines brought a sick man down the river in time to save his life. Lay it on good and strong. Also see that a news story goes out about those three girl scouts that are coming down to join us. One more thing. Work up a good talk about the Henly Health Food stuff for to-morrow night. Better eat a little of the stuff yourself and see what it's actually like. That's all."

He pushed a button and a stenographer appeared, notebook in hand. "Letter to Stanley. Tell him I am definitely leaving for home the first of next month and have him arrange a series of speaking dates. Tell him to see to the publicity a little better than he did last time. We have sent the home office some new material that ought to go over big."

A clerk entered and spoke a name. "Send him in." A bespectacled individual in worn clothing entered. "See here, Miller, you fellows of the scientific staff aren't producing the stuff. How the devil is the publicity staff to work if you don't furnish them with material? You haven't turned in a thing for the last month that they can use at all."

The man flushed. "But, sir, we have been accumulating an enormous amount of scientific material . . ." "Bah! Your scientific material is well enough in its place, but how do you suppose this expedition is to be kept going on scientific material alone? It's publicity that counts in these days and if we don't get it we don't get the money to keep us going and if we don't keep going there won't be any chance to collect scientific material. We need some startling discoveries and if you can't make any, think some up. I don't give a damn for your scientific scruples. As a matter of fact, if it weren't that we need a scientific staff along to keep up appearances we wouldn't bother with you very long anyway. You haven't contributed anything to the movies that we are making. You can't write anything that's worth reading. You'll have to do something to earn your keep."

The man straightened up. "When I joined the staff of this expedition I was not aware that it would turn into a three-ring circus, an advertising scheme and a journalistic venture. My colleagues and I have already determined to leave to-morrow." The director burst out angrily, "There won't be any space in the planes for you. We never agreed to take you out any time you want to go."

The scientist smiled. "Men before us have traveled on foot and by canoe and every other way. The introduction of the white collar, the society element, the automobile, the private yacht and the aeroplane into scientific exploration is really a very recent thing. What men once did we can still do. My colleagues and I have already arranged for canoes. You may go to the devil."

Had any one been watching at the bedside of the sick man he might have been seen to smile as if some momentarily pleasing scene had passed on the troubled current of his dream.

A book-seller's stall glowed with the raw and barbaric colors of book jackets devoted to publisher's blurb, each endeavoring to outscream the others. Among them, side by side with detective thrillers, love stories of the mistresses of kings, popular novels, outlines of this and that, psychologies for salesmen, and outscreaming them all, two books.

"Tropic Night," by Catherton. "This gripping story of intrepid explorers in the gloomy depths of tropic forests . . . love interest running through it . . . a woman and a man, members of a scientific expedition into the miasmic forests of the Amazon . . . primitive passions bursting through the veneer . . . snakes . . . torture of swarming insects . . . gibbering of monkeys . . . sacrifice for science. . ."

"Heart of the Amazon," by Osmand. "This epic tale of daring scientific explorers, enduring the dangers of the tropic jungles, suffering the risk of death from fever and wild animals, plunging fearlessly into the unknown to wrest from it the age-old secrets of the mysterious life that haunts the tropic trails . . . aided by the devices of modern science . . . tremendous contribution . . . its author takes his place as one of the most eminent of scientific men . . ."

The man in the hammock awoke from his troubled sleep with the first light of dawn. Another breakfast of the inescapable tortillas and the inevitable frijoles and then once more behind the plodding burros that carried his equipment and his meager personal belongings he set his feet on the trail to the coast.

THAT SCIENTIFIC HOLIDAY

By Professor A. W. MEYER

DEPARTMENT OF ANATOMY, STANFORD UNIVERSITY

He who proposes a holiday does not take a very large chance on popular acclaim. A day off always is an inviting prospect. The carefree, the irresponsible, the weary, all can forego, or try to at least, not only all thought of the future, but all thought of the present. A joyful or delirious present always helps to efface unpleasant memories, and many of us still like to have a day when and a place where we may say: "Hier bin ich Mensch. Hier darf ich's sein."

Unless they who suggest a scientific holiday consult those without whose sanction and cooperation it can not be had, the suggestion will remain an idle one. For, contrary to the ways of the crowd, scientists are wont to hang "Don't disturb" signs on the doors of their sanctuaries on holidays and lock themselves in, so that they may yield themselves more completely to the lure of the unknown, or, as some people would have it, to the forces of darkness. So a holiday for science without the cooperation of men of science could only be a Volsteadian holiday and would bring us bootleg science as well as bootleg whiskey. Surely, not even the eminent divine, who, among others, suggested such a holiday to men of science, could be thrilled by such a prospect; and it is well to remember that it is not long since the world knew bootleg science, or at least so regarded much of it.

Although it may be true that we learn nothing from history, in spite of the fact that she can teach us so much and so well, I venture to think that it would be possible to revive the old story of bootleg science in a telling way. Galilei and Servetus might tell their story so that people would listen and, listening, would heed the lesson. The rigors of the dungeon and the smell of human flesh, even when burned slowly at the stake on a bright Sunday morning, may not have lingered long in human memory, but in these modern days it might be possible to reawaken that memory with telling effect, for science touches our daily lives in so many ways. Even the untutored could realize what interfering with its growth and living without its commonest fruits might mean.

An untidy or uncomfortable man seldom is happy, and a sufferer still more rarely so. Even common folk know that soap, hot water, towels, clothes and shelter are indispensable and have much to do with their happiness. Add to this clean and sanitary food, comfortable sleep, a wealth of printed matter and access to music and art, ready transportation and communication, skilful help and care and surcease from pain in times of physical distress, and you have some of the commoner blessings of science which have added immeasurably to the happiness of civilized men. Without any of the fruits of science our happiness could be only as that of brute creation, which may seem happy merely because it is dumb, and also without imagination or compassion or remorse.

They who suggest a holiday for science probably forget that it once had a long holiday during dark ages in which life was harsh and hard, and when the human race bore the grievous burdens of plague and pestilence, as well as the dire handicaps of filth, starvation and lack of shelter. In those "good old days" primitive man shared not only the lot of wild creatures, but in a measure and in some respects also the more forbidding

lot of those of the stall. The millennia in which man was indifferent to his surroundings constitute a scientific holiday in fact. Those were the days when man felt no inspiration, dreamt no dreams and saw no visions. Later, when he was stirred into action and became curious about his surroundings, the birth of science had come. Although the entire period of modern science is but as a moment in the long span of man's existence on earth, if those who desire a scientific holiday would have to live a life unrelieved by the fruits of science and by the joy of an inquiring mind, a scientific holiday would lose all its charm.

But this really is not what the sponsors for a scientific holiday want. They merely want to dispense with the future fruits of science. They mean to keep all that which the tree of science has borne in the past, but bid it cease blossoming for a time. They do not want the humanitarian service of science to stop. They do not wish the hand of the nurse and the doctor to be stayed in their ministrations to the sick and the maimed or have the activities of the sanitarian in behalf of public health discontinued. They merely wish to live on the past. This may sound reasonable enough, but is it really so?

Suppose, for example, that the present moment were that of the discovery of anesthesia. Then, what these people really suggest is that the severest suffering should continue unrelieved, that legs should be sawed off and abdomens opened without the relief that unconsciousness only can bring. They would have the sufferer who needs relief by an operation again be held down by force like the worm or the fish on the hook or the cockerel on the barrel. These people would ask that typhoid, diphtheria, smallpox and the plague shall be permitted to go their way as unhindered as they once did and that every house of tender mercy again become a house of needless pain. The suggestion for a scientific holiday can fail to mean this only if it can be assumed that all great discoveries have already been made and that science has nothing more to offer humanity. But were this so, then the suggestion of a scientific holiday is meaningless.

Insulin and vitamins have just been added to the triumphs of medical science, and who can tell what great discovery is in the offing at this very moment. What the advocates of a holiday for scientists apparently fail to realize is that all humanitarian and sanitary measures rest upon pure science, and that it is hence against it that their fears are, in fact, directed. It is exactly these sciences that are the foundations of progress. Here, for example, lies a man severely burned and swollen beyond recognition. Even the nurses and doctors avert their eyes at the harrowing spectacle, and years later dislike to recall it. We shall pass by the long, agonizing and sleepless nights and days which the victim would have to bear if there were no hospitals and if there were no drugs to deaden feeling and prevent infection. But suppose every doctor's office contained the means of neutralizing the effect of the poisons produced in the burning of the flesh and hence could forestall the dreaded early collapse and later complications and perhaps death. Were this possible, wife and children, perhaps far distant from the scene of tragedy, could be saved the dreadful suspense of many uncertain days, and could often be apprised almost at once that all would be well in the end. Is there any man so stupid or so cruel as to want to stay the hand of him who might bring us this relief? Could those who suggest a holiday for science go through the nerve-wracking experience of witnessing such pitiable spectacles as those which often follow severe burns or

scalds or be so unfortunate as to furnish such a spectacle themselves, they would be the first to further the progress of science instead of wanting to halt it even for a moment, for surely some moment will tell the secret of cancer and of leprosy.

It is only the investigator in pure science who can determine what the toxines are that produce the dreaded effects of burns, who can learn how they act and how they may be neutralized; and until these things are known, doctors and nurses, be they ever so faithful and competent, will remain helpless to relieve the greatest sufferer. Surely no man of God will want to be responsible for delay in this matter. A brief holiday could be of no avail to any one, and a long one would break all continuity with the past. It is possible to bid the tree of science cease growing, but no man can cause it to blossom again forthwith. Dead trees can not be revived; and, like all other trees, the tree of science does not prosper without care. Be he ever so humble, the man of science can not be made to arise by a wave of the magician's wand. He too is born, and dependent on the past. Not even a genius could do much if compelled to start anew.

He who created all things must also have created the scientist, and a scientific holiday implies that scientists must, of necessity, become misfits or idlers. Scientists did not create their own predilections. These were born with them quite as much as the predilections of any other group, and they can not successfully cultivate a taste for things for which they are not fitted. The curiosity which they evince concerning their surroundings is inborn, not acquired.

Men do not create, but develop, their capacities, and if science is not a part of the eternal scheme of things, then it must lie within the power of the groping, puny mind of man to circumvent the Maker of all things. Surely not even the most confident or arrogant man of science would claim this. And if no one can, or tries to, outwit nature or the Creator, then why all this alarm, for the man of science, too, is a worker in the vineyard of the Lord, misunderstand and misuse him in war or peace though we may.

The idea that science shall mark time so that somebody else may catch up is, indeed, a novel one. It implies that others can not or will not quicken their pace. Science must move on. It is not a mere sapper, but lays foundations without which progress is impossible in modern life. All uncivilized peoples have had abundant time to achieve greater happiness than the civilized, had this been possible without science, and if there be those who perchance hold that aborigines have indeed done so, let them volunteer to share their bestial life.

It also is well to remember that the so-called onward march of civilization never has presented a straight front. It always has had its scouts and its stragglers, as well as its main line, and it probably always will have them, with a long stretch from front to rear. Both ends may be happy, but only because the rear is unaware of, or else because it enjoys the protection of the advance guard.

Until progress in science ceases altogether, readjustments in our views regarding the world of nature are inevitable. If we do not make these inevitable readjustments ourselves, we will merely be passing the burden on to others and our children will of necessity have to make them instead. However justifiable it may be to visit pecuniary burdens upon future generations, we surely should not visit intellectual burdens upon them in addition.

The suggestion for a scientific holiday seems but a jest, and, when made in earnest, can not be the fruit of either the humanities or of religion, but must

arise from the fears of men who have lost their way, as others did before them. A life in conformity with the laws of science need give no one trouble, for it implies living in conformity with the laws of nature, which also must be the laws of God. If there be a conflict between the laws of matter and those of the spirit, it must have been so ordained, and it can not be in the power of any man to avoid that conflict. If, on the other hand, no such conflict exists, then he who obeys the laws of nature need not violate those of the spirit. To live in conformity with natural laws may not of itself bring happiness, but it surely will avoid much unhappiness.

Science can not solve the riddle of the universe, but neither has anything else done so. All roads have been blind alleys and an *ipse dixit* remains just that, no matter whether it comes from the lips of the man of science or from those of the man of God, and can bring happiness only to those who are pleased to accept it with unquestioning faith.

In the wide span of human history it was but as yesterday that the use of knives and forks and spoons was declared to be sacrilegious because the Creator had provided ten fingers for these very purposes. There are those living now who remember that the use of anesthesia in childbirth was denounced because it was thought to remove the curse upon Eve from woman, and thus circumvent the intentions of the Creator.

They who would halt the builders in the temple of science to allay groundless fears and to avoid inevitable readjustments in conceptions regarding the universe are men of little faith. Take heart, I say, and let not the arrogant, the overconfident and overzealous among men of science frighten you with boastful things. False prophets in the field of science, as in the realm of religion, are sure to be revealed in their true light, and it is our fears that often bring us our worst perplexities. If, as men blinded by prejudice or wrath, we wreak our vengeance upon things that have freed us from grievous bonds, we may again become galley slaves brutally scourged to foul dungeons or pitilessly consigned to the boundless deep.

ON THE DIFFICULTY OF CONVEYING IDEAS

By Dr. BEVERLY L. CLARKE

MEMBER OF TECHNICAL STAFF, BELL TELEPHONE LABORATORIES, INC., NEW YORK, N. Y.

EXCHANGE of thought through the medium of words is hedged about by difficulties which stamp informal conversation definitely as an art and not a science. In other words, the *idea* in the mind of the speaker is transmitted, through language, not pure and untainted and "under seal," as we should wish, but tinged and twisted and disfigured. This is partly owing to the inherent imperfections of language and of our conventional method of translating thought into words, and partly to personal idiosyncrasies of the minds of both speaker and listener. These latter operate to cause the speaker to say something different from what he is thinking, and the listener to construct in his mind an idea different even from that implied in those inaccurate words.

There is a remarkably pertinent analogy in the radio. A band plays in New York, and the sound waves enter the microphone and are translated into

electricity. The method of translation is not perfect, and the electrical waves are not exact replicas of the sound waves. The electrical impulses are further changed and sent out into space as "ether" waves. Between the broadcasting station in New York and the receiver in Chicago the "ether" wave is subjected to countless forces which further distort it and render it less a "literal translation" from sound into electricity. In the receiver the poor wave is further mauled by mechanical and electrical imperfections, is retranslated into sound and finally arrives bearing but little real resemblance to the band music in New York, and accompanied by a host of squeaks and squeals and buzzes and wails that it picked up on its way or in the receiver itself.

So it is with the broadcasting of thought. The transmitter and the receiver are both imperfect, and insist on making contributions and paraphrasings of their own. The medium—language—abounds with static and cross-currents, and "fading" is not altogether unknown.

Perhaps the chief difficulty lies in our method of attempting to frame ideas into words. Language is inherently inadequate for the full expression of the simplest idea. Language is man-made, and ideas are sublime; they are possibly the very atoms of consciousness, of life; they are essentially transcendental and intangible.

If we attempt to elaborate on the concept "idea," to delve deeply into its form and essence, and so to characterize it by a statement of its peculiar qualities and attributes that its utterance by a speaker will convey exactly the same impression to every listening mind, then we become immediately conscious of the limitations of language. "Idea," as used in the present essay, is to be loosely identified with the more current word "thought," in the sense of the "quantum" of thinking; and the thought is the thing-in-itself, the reality, the actual noumenon which results from the activity of mind. The thought, or the idea, is thus suggested as a mere synonym for mind-in-action; static, inactive mind, is unknown to us and inconceivable by us, and is the utterly unattainable thing-in-itself of which the idea is the phenomenon or manifestation in the next lower sphere. Similarly, the attempted expression of a thought in language is an imperfect manifestation, in a still lower sphere, of the idea.

Thus verbal expression is twice removed from the absolute truth, and is grossly distorted in each of the two steps. It is as if we were translating a German passage, first into French, which corresponds to passing from absolute truth or static mind to the result of mind-in-action or the idea, and then from the French version into English, which parallels our attempts to formulate ideas into words. The translations lose something at each step, and the final English version may easily be unrecognizable to the German author. Is it not possible that a correspondingly important loss is suffered in passing by this tortuous route from the absolute truth to expression in language?

In any consideration of the transmission of ideas from person to person through language, it is manifestly necessary to make the empirical assumption that the word "idea" means the same thing to every mind. Any conclusions we may reach will have meaning and significance only in so far as this assumption is warranted. Fortunately, and rather paradoxically, the concept "idea" seems, in spite of its extreme abstractness, to possess in extraordinary degree this quality of universality of significance.

If we grant to "idea" this universality of significance, then we avoid the first stumbling-block which the difficulty of conveying ideas redundantly places in the way of any consideration of this diffi-

culty as an abstraction. Even though we might not be entirely justified in this simplifying assumption, we should have to make it anyway; otherwise there would be no place to begin.

Because of some peculiarity in the way our minds are made, we are compelled to make our thoughts articulate either by stating an abstract generalization or by quoting a specific example. Without endless circumlocution there is no middle ground. Neither one of these is entirely satisfactory and neither one is exactly what we want to say. If, in extemporaneous conversation, we express our thought of the moment by some broad, sweeping, all-inclusive generalization, such as, "My life is a pretty gloomy affair," then we say a great deal more than we intend to say. Still, if we trace the origin of that thought and put that little stimulus into words, it may turn out to be, "I have a pain in my stomach from that lobster, which makes me very uncomfortable." To say so baldly would, however, fall far short of the mark of accurately rendering what is in our mind; because the stomach ache which possesses our attention for the moment has acted as a nucleus around which has gathered a number of other equally minor matters of similar character drawn from memory, the result being a sizable heterogeneous mass which, for the moment, appears homogeneous and important.

In this day, when brevity and succinctness of expression are at a premium and catch-phrases and slogans are applauded as linguistic achievements, any tendency towards circumlocution is frowned upon, and the writer or speaker who attempts, by qualifying phrases and logical embellishments, to make his words render his thoughts more truly is damned as a pedantic bore, bombastic and heavy.

So it appears that there is indeed no possible middle ground. Also, it appears to each of us, on introspection, that the mind, in its operation of fabricating ideas, makes use of a form which is neither abstract nor narrowly specific, but which lies somewhere between the two. The mind thinks, then, in a framework which, through some curious caprice of the nature of things, has no exact counterpart in linguistic expression.

Let us turn now to the hearer of the words which are spoken in an attempt to convey to his mind the ideas which originated in another mind. This person receives an impression in his brain through the spoken words which we shall, for the moment, assume to be identical with the best possible translation into words that the speaker could make of his idea. The recipient then retranslates this impression into thought substance. The assumption is usually made that, after these several translations and retranslations, the idea which finally lodges in the hearer's mind is a faithful reproduction of that which was present in the speaker's mind. But this is obviously not true; for one thing, because of the indefiniteness and inefficiency which characterizes this shift from a form which is definitely abstract or definitely specific, to one which must partake in some intangible way of both in order to fit into the matrix of the mind.

And there are other factors operative which tend greatly to increase the degree of inaccuracy possible. One of these is that, in passing from the abstract (or from the specific) to this peculiar intermediate point, it is necessary for the mind to use its powers of reason and analysis and to exercise its faculty of judgment: it must apply criteria, weigh evidence and act as an analyzer of motives. For its task is to try to fathom out the real idea in the other person's mind; the words are only a clue, and with their reception the detective work only begins. And it will be generally admitted that, unless we attend closely to make it otherwise, the mind is inclined to be very decidedly biased and preju-

diced in its judgments and analyses. The bias is derived from the past experience and is moulded by the present mood of the mind itself. The mind which attempts to translate words heard into an idea must perforce do it in the same way as it would have performed the reverse act of changing its own idea into words. The indications are that no one mind is exactly like another in the method it uses for this purpose, because, as stated, its own peculiar method is determined by its past history and present state. Thus, on hearing the statement, "My life is a pretty gloomy affair," the listener, if by chance he had a digestive system which rose above mollusks and bivalves, would not in a thousand years deduce from the evidence at hand that this devastating affirmation had such an origin. He might, on the other hand, have learned of a fall in certain railroad stocks in which he knew his interlocutor to be interested, and the probabilities are that he would attribute his pessimistic statement to this—and be altogether wrong.

Words are to ideas what weight is to matter: their effect is to impede the movement, distort the form and thoroughly to cloak the essential lightness and ethereality that properly belong to ideas. But their offense is ranker even than this. We have been discussing the shortcomings of the verbal expression, that is, of the group of words, in expressing an idea. But it is manifest that the individual words constitute the root of the trouble. Consider what a simple substantive, such as "dog," means to various minds. To me, when I forcibly close my mind to the several specific dogs with which I have been familiar, and try to visualize the general abstraction "dog," there arises a picture of a hybrid beast with long, flabby, white ears, the kind, trusting physiognomy of a collie, an emaciated body, creamy-white mottled with black spots, a most incongruous abbreviated tail, and dark-colored spindly legs. Evidently this bizarre creation is a composite of a number of dogs whose external characters have stuck in my memory. Try as hard as I will, I can not devise a picture of "dog" which satisfies my desire for the universal abstraction divorced from individuals. You, the reader, will doubtless find in your mind a picture of "dog" considerably different from mine, for the simple reason that you and I have moved in different dog societies. All of which admirably illustrates the point that any word will mean something different to every one who hears it. With some words the discrepancy is great, with others small; but discrepancy there always is. If such common and universally familiar words like "dog," "man," "boat," etc., suffer from lack of stability to such an extent, how can we have faith at all in abstract words like "love," "good" and "right"? Plato wrote his "Republic," a lengthy work, in an attempt to establish a definite meaning for one little word—"justice."

Thus we must conclude that when a person pronounces a single word in an attempt to convey an idea to another, he has little assurance that the image aroused in the other's mind will bear much resemblance to that in his own. The mental image which a word brings up is moulded and fashioned by the past experience of the individual. Each time a dog is seen a contribution is made to the individual's concept "dog"; and each time a dog is thought of in relation to other ideas, emotions or events the concept is further amplified or altered or, it may be, drastically redesigned. Thus a man who was bitten by a mad dog would inevitably allow this particular dog a large share in the development of the abstract concept.

If there exists this much uncertainty about single words, the frightful risks we take when we string several words together may readily be imagined. For here we introduce the added danger of

the attempted fusion of several abstract concepts to make a single concept less abstract and more particular. For this reason, the total ambiguity of the verbal expression is more than the sum of the ambiguities of its component words, by an amount which defies estimation because it deals with the transcendental matter of *relation*. It is truly marvelous that, with this formidable misfit of language with ideas, one human being is able to hold any sort of mutually intelligible intercourse with another. What is lacking in this field is similar to what Einstein found to be lacking in the physical universe: a universal frame of reference, rigid and unchanging from point to point in the universe—or from individual mind to individual mind in the sphere under discussion.

Besides the use of words simply as practical symbols for ideas, there are of course other methods of conveying from one mind to another the results of mind-in-action. If we designate the method which we have been discussing as the literal method, we may group all others under the esthetic or symbolic method. In the literal method words are simply convenient and practical shorthand characters for definite ideas. The important distinction is that in the literal method, for every possible idea there is a word or a word-group which stands for this idea and for no other. This would be possible theoretically if it were true that words can unambiguously express an idea, because one can conceive of an infinite variety of words or word combinations to fit the infinite number of ideas; but it does not work in practice because, as we have seen, words and ideas are essentially incommensurable. The literal use of words in straight prose and the use of pictures as aids in language instruction, such as the picture of some animal with its written name attached, are examples.

At the opposite pole lies the esthetic method. Here the analysis of purpose and motive is difficult. The physical form of the medium used for the conveyance of the idea is not to be regarded as a literal and invariable symbol for the single idea, but rather for an intricate complex of ideas which resists analysis. Thus, while one can conceive of assigning a fairly definite and nearly universal meaning to "dog," no two people, and least of all no two estheticians, can agree upon the fundamental idea which a portrait of Titian or a symphony of Beethoven ought to convey.

But the esthetic and the literal methods are, in one sense, two methods of doing the same thing. An artist, or a composer, or a poet, in fashioning a symbol in his particular medium, has one thing in common with the prosaic utterer of a brief, unembellished verbal expression: he is attempting to translate into another medium an idea or an idea-complex, which is in his mind. The two operations are fully analogous: both have as their unconscious purposes the desire to express an idea; both make use of a medium. The difference is that with words the ideal universality of significance is comparatively closely realized; whereas in the arts the same symbol (poem, painting, sculpture, etc.) admittedly produces widely differing reactions in different individuals. No one but an idiot would picture a horse in his mind when some one pronounced "cat"; but there could be selected a group of people, none of whom would be idiots, whose individual opinions of some picture or symphony would run the adjectival gamut from "hideous" to "celestial."

That this is only a difference of degree when the verbal and artistic forms of expression are concerned is illustrated by the facility with which people justify diametrically opposed lines of conduct by the same written words; witness the familiar platitude, which is true enough, that "you can prove anything by the Bible." Prose such as found in legal documents falls under literal method,

while poetry makes use of the esthetic method; but most poetry contains considerable prose and most prose considerable poetry. There are extremes, as, on the one hand, verbal statements of mathematical laws, where a serious attempt is made completely to eliminate ambiguity, and, on the other, certain sacred writings of the Orientals, with whom obscurity seems a virtue and an index of profundity. But there are all possible gradations between the extremes, and the two methods of conveying ideas nearly always overlap.

But it is perfectly evident that the artistic symbol is ill adapted to the definite, unambiguous conveyance of an idea. The user of the esthetic method does not imagine that his exact mental content will pass over, through the medium of his art, to another mind; he knows well enough that it will not. The idea-complex which the sight or the hearing of his artistic product will induce in another mind depends almost entirely upon the past history of that mind, upon its peculiarities, its ancestral heritages, its momentary caprices, in a word upon the *personality* of the owner of the mind.

How then can a sane man devote himself to the expression of his ideas by a method which gives no promise of accurately conveying them to other minds? Are we to conclude that the employment of an artistic medium of expression is a vain and futile occupation? We are indeed so bound, if we make no distinction between the motives which prompt the user of the literal method and those which are at the root of artistic endeavor. But we are intuitively averse to placing Michael Angelo, who was a Symbolist, at a lower level in the scale of mind than the Italian fruit peddler, who is a Literalist. So we cast about for some illuminating difference in motive.

This difference in motive is soon apparent. The artistic urge comes from a subconscious conviction that the difficulties of conveying ideas are insurmountable. It is a recognition by the artist that his idea-complex *can not* be adequately and completely transmitted to another mind. Released, by this conviction of the futility of the literal method, from the cramping chains of prose verbal expression, he turns joyfully to the more fluid media of art, and there moulds, paints or composes a symbol which he strives to make a perfect physical correlate of his idea. By the same action his obligations to the other minds that fill the world are dissolved, and he balances himself upon the cold pinnacle of isolated individualism; for when he becomes an artist his purpose ceases to be the *conveyance* of ideas, and comes to be simply their *expression;* his artistic urge is satisfied completely by having carved out of the formless medium a perfect, literal symbol of his ideas; he has not the slightest concern with what ideas his product arouses in other minds.

If we granted the validity of this interpretation of the impulse to artistic creation, we are in a position to make some generalizations about the character of the true artist, the flattering nature of which would have a tendency to induce in our artist an excessive vanity—were he not a *true* artist and hence immune to flattery and utterly indifferent to what we may say or write about him. If our explanation of his motive is correct, the artist must be placed, by all real standards, above those of us who are not irresistibly impelled to create; for this impulse is the direct result of the existence in the mind or soul of idea-complexes too abstract, involved and advanced to admit of their satisfactory expression by the literal method: if the content of the mind is of the simpler variety, the literal method will suffice; and the spontaneous confinement of an individual to this mode of expression is an index to a mental or psychical caliber

inferior to that of his neighbor the artist who deals in symbols and scorns praise.

But before the professional dealer in artistic symbols may gracefully accept this pean of praise, he has the difficult task of justifying his claim to the title of true artist. It is not sufficient that he feel the urge to paint or write romances or play the piano; it is not merely that he allow these impulses full play and acquire the ability to produce from his medium creations which draw praise from the critics and acclaim from the populace. For the true artist success is measured not by the pleasing impression produced on others but by the accuracy and completeness with which the idea-complex in his mind finds expression in the medium; it is a matter concerning the artist and his medium exclusively, and incidental auditors, witnesses or readers are simply interlopers who indelicately intrude upon a private affair and are to be ignored.

Now it is a matter of common knowledge that artists, as a class, are deplorably vain about their creations. What prima donna regards the audience as indelicate intruders? Or what pianist laboriously masters the intricacies of Bach or Beethoven for the sole purpose of performing them for his own ears? Are we then to refuse to any whom we call artists the supreme title of *true* artist? Happily we are not forced, by logic, to such an extremity. It is only necessary to remember that an individual is not homogeneous but extremely heterogeneous, and that the human personality is not simple and static but many-sided and changeful. We avoid the difficulty by considering that the personality of an individual is compounded, like a chemical substance, of different proportions of a number of elements, one of which may or may not be that of pure artistry. When this element reaches a certain degree of predominance, the individual takes on the characteristics we commonly associate with the artistic type. From then on, with increasing proportion of the artistic component, the artist approaches nearer and nearer to the true artist.

Plainly, we are postulating true artistry as an ideal state, probably unattainable in practice. Like the truly just or the truly good man, the true artist is of the nature of a mathematical limit, to which we can approach as closely as we please—theoretically—but which we can never quite reach, even theoretically.

It seems, then, that the difficulty of conveying ideas is not, after all, so much to be deplored. For it is this very difficulty that has given birth to art; and few will deny that we are indebted to these rare and brilliant flames of pure artistry which now and again illumine the world, for most that is excellent in this life.

SOUND PERCEPTION BY INSECTS

By Dr. B. B. FULTON

NORTH CAROLINA STATE COLLEGE

It would seem like a very foolish whim of nature to provide many insects with elaborate sound-producing mechanisms if they could not hear their own music. But any one who studies living insects must notice their apparent indifference to the sounds we make. You can shout at an insect until you are blue in the face, and as long as no air currents strike it the insect goes about its business as if nothing had happened. Either it does not hear you or if it does it seems to consider the source and pays not the slightest attention. This lack of response to sounds has led many people to believe that insects are unable to hear.

The most commonly accepted theory regarding the utility of insect sounds is that they are mating calls. If insects do not hear, this theory would have to be discarded. Fabre claims to have fired two mortars near singing cicadas without affecting their song. He says, "If any one should tell me that cicadas strum on their noisy instruments without giving thought to the sound produced and for the sheer pleasure of feeling themselves alive, just as we rub our hands in a moment of satisfaction, I would not be greatly shocked." Lutz questions whether the sounds produced by some insects have any more purpose than the snoring of a man asleep or the rattling of a Ford. Forel, after experimenting with various types of sounds with a number of different insects, concludes that only crickets and certain other Orthoptera actually hear, but that all insects are remarkably sensitive through their tactile sense to vibrations of the ground or objects on which they are standing.

If it could be proved that insects do not hear, then we would have to find a new use for certain peculiar structures which insect anatomists call auditory organs. Our knowledge of these organs is the result of many years of painstaking research, mainly by German entomologists. The first hearing organs to be investigated were those associated with an external tympanum or ear-drum which any one can find with a hand lens on the front legs of crickets and katydids and at the base of the abdomen of short-horned grasshoppers. The sensory cells associated with all such organs were found to be characterized by the presence of a peculiar hollow rod which may be called the auditory peg. This tubular structure is imbedded in one end of a spindle-shaped sensory cell and the axis fiber of the cell extends through the tube just as a fiddle-string might be stretched through the center of a length of pipe. In the other direction the axis fiber is connected by nerves with the central nervous system of the insect. It would require about seven hundred auditory pegs placed end to end to measure an inch.

Further investigation revealed the fact that insects of various groups possess sensory cells with auditory pegs which are not associated with ear-drums. They are usually found in bundles and suspended by means of ligaments between two immovable points of the insect's body wall in such places as to be free from the movements of the inner organs. They are found in larvae as well as adult forms, and in various body regions, such as segments of the abdomen, in joints of the antennae, in legs and in wing veins. It is believed that

the integument of insects, like the eardrums of vertebrates, may act as a sounding board to pick up sound waves from the air and transmit them to the auditory sensory cells.

Large bundles of auditory pegs have been found in the enlarged basal segment of the antennae of mosquitoes and many other insects. It is believed that the small bristles on the outer segments of the antennae pick up the vibrations and transfer them to the nerve endings in the basal segment. In the case of the male mosquito whose bristles decrease in length toward the tip of the antenna, it has been demonstrated that different musical notes will cause different sets of bristles to vibrate. This experiment does not actually prove that mosquitoes hear with their antennae any more than it could be proved that a piano hears when its wires are set into sympathetic vibration by sound waves. The mosquito gave no indication that it perceived any sensation of sound.

The difficulty in demonstrating that an insect hears has been to find one that will react frequently to some sound that we can make. If all animals reacted to every sound perceived, what a lively place the world would be. But a few cases have been discovered where for some unknown reason an insect will show a definite movement in response to a sound.

Turner experimented with some of the large native silkworm moths and found that by suddenly sounding an organ pipe or whistle in the insectary the moths would lift their wings as if about to fly. This happened in a sufficient number of cases to show that the movement was definitely associated with the sound. Precautions were taken to prevent vibrations reaching the moths in any other way than as sound waves in the air. The moths responded to a rather wide range of sound waves.

One species, *Telea polyphemus*, responded very little to the sound, for out of seventy-eight trials the moths gave only three positive responses. The question was whether this species was hard of hearing or merely unemotional. To test this he performed some experiments on one individual at a time. After sounding the organ pipe five times he would take this moth and squeeze it, throw it down on its back and manhandle it in various ways without seriously hurting it. This was repeated a number of times and in this way he claims to have educated several specimens so that they moved their wings vigorously whenever the pipe sounded and did so on the following day also.

Turner and Schwartz tested the auditory powers of certain moths of the genus *Catocala* which have a habit of resting on tree trunks during the day, their brightly colored hind wings covered by dull-colored fore-wings that blend with the bark. Whenever they found one of the moths in the woods one of the partners in this experiment would sneak up on the opposite side of the tree and blow a high-pitched Galton whistle, while the other would observe the moth at a safe distance. In the majority of trials the moth either flew or fluttered its wings at the first sound of the whistle.

Minnich found that the larvae of the mourning-cloak butterfly, *Vanessa antiopa,* would respond to a sound stimulus by suddenly raising the anterior third of the body. When the body hairs were singed off or loaded with water or flour the response was reduced or abolished. During molting periods, when the old and new hairs became partly disconnected, hearing seemed to be impaired. It was evident that the hairs were organs of sound perception. The larvae responded to a wide range of sounds from 32 to 1,024 vibrations per second.

More recently Abott has demonstrated a more limited degree of sound perception in the yellow-necked caterpillars, *Datana perspicua*. These larvae feed in

colonies on sumac and when disturbed elevate the front and rear portions of their bodies. They responded in this manner when a pipe was sounded if the note was either middle C or F sharp above middle C. Here again the body hairs seemed to be associated with sound perception, for the response was destroyed when the hairs were sprayed with water or diluted shellac. In neither this experiment nor the last was it shown that the hairs are associated with auditory sensory cells.

During all the years that entomologists have debated the question of whether insects can hear, and while they planned and carried out careful experiments to prove it, a modest, retiring insect has been steadily broadcasting to the world that it can hear its own kind. That insect, the snowy tree cricket, is seldom seen, but its song has been heard and admired the country over. No experiment is necessary to show that it can hear; one has only to listen and observe. The measured, mellow notes, as they issue from the thicket on a summer night, seem to be the effort of a single singer, but in reality they may be the perfectly synchronized music of a dozen or more. This insect is a lover of rhythm and each individual is part of a leaderless orchestra. In what other way can these musicians of the dark coordinate their notes except by the sense of hearing?

I have also observed this habit of synchronized stridulation in two species of the katydid family, but it is not common among singing insects. Probably others fail to practice it because they lack a talent for rhythm and not because they are unable to hear each other.

In northern Arizona I have observed a species of grasshopper, *Circotettix coconino* Rhen, which effects periodical community outbursts of a loud rattling noise made with the wings while putting on an exhibition of stunt flying. At intervals of about half an hour I would hear some of these grasshoppers flying in the distance. The sound would approach and suddenly several of the insects near by would take to the air and make the desert ring with a terrible clatter. Then they would settle down and I would hear the wave of disturbance passing on to other parts. How do these grasshoppers, resting on the ground, often under the plants, know when it is time to perform their aerial antics except by the sense of hearing?

It has been demonstrated by experiment and observation that some insects can detect sounds. We have the word of the anatomists that a great many and perhaps all insects possess sensory organs containing auditory pegs, which seem to be better fitted for hearing than for any other function. It seemed to me desirable to tie up the two lines of evidence by an actual demonstration that the organs in question are the ones concerned with hearing.

The crickets and katydids that practice synchronized stridulation are ideal subjects for such an experiment. They demonstrate hearing of their own accord and they wear their auditory pegs in specialized structures on their front legs where they can easily be removed without seriously injuring the owner. What could be simpler?

The first species I experimented with was a short-winged katydid, *Amblycorypha rotundifolia brachyptera* Ball, an inhabitant of the Iowa prairies. The song of this insect is a series of twenty to thirty sharp metallic rasps at the rate of about four per second. Each series of notes is followed by a rest period of about five seconds. In common with all crickets and katydids the sound is made by short wing movements. A specialized file-like vein on the under side of one fore-wing near the base is scraped by the edge of the opposite wing. The synchronism exhibited by ten males that I placed in a cage was almost perfect. The song of the group was continuous, and as each singer started its series of

notes anew it would fall in with the general cadence. It was only by detecting slight variations in the quality and volume of the chorus that one could be aware of the pauses in the individual songs.

I next placed four of the singers in another cage at some distance from the first and with a small scissors cut off their front tibiae, leaving them without their supposed hearing organs. On the third night after the operation two of the mutilated katydids sang more or less continuously. The notes were not synchronized except as they happened to sound together at times. The two males sang at slightly different individual rates so that if they started a series of notes in unison, they would be sounding alternately at the close. Later, three or four of the deaf katydids could be heard singing at once, with a confusion of sounds that would have inspired a composer of rhapsodies.

The normal katydids continued playing their synchronized music. In order to be doubly sure that my expectations did not deceive my senses, I requested some one who had no knowledge of the experiment to listen for a few minutes at each cage. This observer noted at once that the song was rhythmical in one cage and a medley of confused sounds in the other.

The next number on the experimental program was a male chorus of snowy tree crickets, *Oecanthus niveus* De Geer. Their song is a clear, whistling note rhythmically repeated for an indefinite period. One lot of the crickets had their ears amputated as in the previous experiment, and the results were essentially the same. When only two of the mutilated musicians were singing at once the notes were apparently synchronized at regular intervals, separated by periods during which the notes sounded alternately. This effect is produced by any two sets of rhythmically repeated sounds having slightly different frequencies. Each cricket sang at its own individual rate uninfluenced by the song of others in the same cage. When three or more were singing at once an utter confusion of notes resulted, so that the rhythmical quality of their song was entirely obscured.

The song of the normal tree crickets in the other cage presented a striking contrast. Each individual sounded its notes in unison with the others as if a single cricket were singing.

The third insect tested was the Nebraska cone-head, *Neoconocephalus nebrascensis* Bruner, a member of the katydid family with slender green body and a head drawn out into a point in front. Its song consists of a continuous series of rasping, buzzing notes lasting a little over a second and separated by about equal intervals of silence. I have observed this species in the field synchronizing their notes at a distance of twenty paces between singers. Only four males were used in the experiment, two without front tibiae and two normal ones. On the second evening of the experiment the two earless cone-heads were singing with a very conspicuous lack of coordination. For about a minute their notes would sound alternately, then gradually one song would catch up with the other so that for another similar period the notes would sound simultaneously. At the same time the normal cone-heads were keeping up perfect synchronism. Sometimes one note could be heard to start a fraction of a second ahead of the other, but never once did I hear them entirely separated.

It might be argued that the insects without their front tibiae acted differently as the result of shock to their nervous systems received during the operation. This is extremely improbable, for the insects with bobbed front legs appeared to enjoy as excellent health as the normal ones and lived fully as long. Moreover, they never recovered in the slightest degree their ability to syn-

chronize. Among such insects the loss of a leg is a matter of small conseqence. If they are held by the hind legs when captured they will often voluntarily kick off one or both in an effort to escape.

There is also a possibility, although a remote one, that the real hearing organs are concealed somewhere in the lower part of the tibiae or in the tarsus. Since these experiments localize the sense of hearing so near the tympanum or ear-drum with its bundles of sensory cells containing the so-called auditory pegs, there is little doubt but that sensory cells of this type are the organs responsible for hearing in insects.

We still leave unanswered the question of what range of sounds the crickets and katydids can hear. Do they merely hear the music of their own kind or do they hear many other sounds as well? This probably varies with each species, just as was found in the experiments with moths and caterpillars.

I regard as purely academic the question of whether sound waves arouse in insects the same sort of sensations that they do in man or whether the insects merely feel a tingling sensation as we might feel the vibrations of a violin string by touching it with a finger. The settlement of this question may have to wait until insects have evolved sufficiently in intelligence to have a written language and practice the indoor sport of introspection. The fact remains that insects can detect certain sound vibrations transmitted by the air and that they can react to them about as quickly as the higher animals do.

Granted that the crickets and katydids can hear their own kind, the reason why they sing to each other still remains shrouded in mystery. Why do some species maintain synchronized orchestras and others remain soloists? There is reason to believe that the primary utility of an insect's song is to call a mate, but their musical efforts seem to be carried to an excess not demanded by that purpose. In most cases the singing males seem to seek out the mute females. But the wing structures responsible for the music of insects were evolved eons ago under conditions about which we can hardly even guess. Nature goes to excess in most things. Possibly insect songs have no present utility at all, but the musical instruments have been retained, even perfected and specialized, because they were not harmful to the species possessing them.

WILL THE NEGRO SURVIVE IN THE NORTH?

By Professor S. J. HOLMES
UNIVERSITY OF CALIFORNIA

TEN years ago most students of the subject would have answered in the negative the question which forms the title of this article. Probably many of them would give the same answer to-day. But the vital statistics of the Negro have recently undergone such marked changes that the question is at least debatable, and if it should turn out that the affirmative answer is the correct one the matter is of grave concern for the racial composition of the American people, north as well as south.

The first decades after emancipation witnessed a rapid growth of our Negro population which afforded the occasion for widespread alarm. Between 1860 and 1880 the Negroes increased from 4,441,830 to 6,580,793, and by 1900 they numbered 8,833,994. This rather striking increase led several writers to express the fear that the country was on its way to becoming a second Haiti. However, the census returns of the last three decades showed that the Negro population, while continuing to grow, was increasing at a diminishing rate, and that the whites were multiplying much more rapidly than the Negroes. The fear of being swamped by the rising tide of black humanity has now mainly subsided, and some students of population problems have recently expressed the conviction that our colored inhabitants will soon be actually decreasing in numbers and that the race problem will ultimately solve itself. As far back as 1896 Dr. F. L. Hoffman made such a prediction in his well-known essay on "The Race Traits and Tendencies of the American Negro," and similar views were championed somewhat later by Dr. Corson in a fairly extensive survey of what he termed the vital equation of the Negro race. Both of these writers contended that the Negro was ill adapted to survive in competition with the white man. It was pointed out that the mortality of the Negro had been steadily increasing since the period of slavery. Suddenly freed from the surveillance of their white masters, the Negroes were forced to live under very unsanitary conditions and death became a frequent visitor to their squalid homes. Venereal diseases, tuberculosis and pneumonia ran riot; infant mortality was frightfully high, and although births came with unabated frequency, the vital prospects of the Negro seemed, on the whole, very unpromising. The conclusion appeared to be warranted that the Negro is a biologically unfit product who would be taken care of in due time through the drastic agency of natural selection.

This conclusion inevitably raises the question whether the high mortality of the Negro is due to his inherent physical inferiority or to the unfavorable conditions under which he lives. Undoubtedly hereditary racial factors influence the relative mortality of whites and blacks. There are several diseases to which Negroes are relatively unsusceptible. There are others, such as pneumonia and tuberculosis, to which the Negro falls a prey to an extent which can hardly be accounted for by his relatively unhygienic surroundings. The death-rate of the Negro population, however, has shown a marked decrease in the past three decades. So far as can be ascertained from our fragmentary data, Negro mortality reached a climax somewhere in the eighties. The mortal-

ity rates of the censuses of 1870, 1880 and 1890 are practically worthless, and we have to base our conclusions on the statistics of the few states and cities which kept adequate records during these periods. Taking the death-rates of the white and colored population in the registration area we find the following trend:

Death-Rates of the White and Colored[1] Population of the U. S. Registration Area, 1890 to 1920

	1890	1900	1910	1920
White	20.22	17.1	14.58	12.59
Colored	32.4	29.4	24.1	18.00

The Negro rate is still much the higher, but it is not so high as the white rate thirty years ago, and in many places it has declined at a more rapid pace.

Hygiene and public health measures are doing much to lengthen the average life of the Negro. The control of epidemics and the various means which medical science has discovered for the prevention and cure of disease have conferred their benefits on whites and blacks alike. Death-rates will decrease more slowly as the average duration of life approaches the natural limit of human longevity, and we can therefore look forward to a more rapid decrease of mortality in the Negroes than in the whites. The average duration of human life has been prolonged, not through an extension of its natural span, but by reducing the mortality of its early and middle periods. It is in these periods that the mortality of the white and black races differs most widely. It is in these periods also, and especially in early life, that death-rates are most readily affected by environmental causes. How closely the mortality of whites and blacks can be made to approach it is impossible to predict. Perhaps racial susceptibilities to certain diseases will continue to cause differences in mortality which no environmental changes will be able to eliminate. But, however this may be, it is unquestionable that great reductions in Negro mortality may be made before this limit is reached.

Since the mortality of the Negroes has undergone a marked reduction it is evident that their slackening rate of increase must be due largely to the decline in their birth-rate, although this decline has not been so rapid as in the whites. The excess of births over deaths has been lower among Negroes, but it has shown a tendency to approach the white rate in most of the states included in the registration area for births. In several northern states the Negroes have the higher birth-rate, but as a rule their mortality has been so high as to bring their net rate of increase below that of their white competitors. In the light of recent vital statistics, however, one can not be sure that this condition will last long.

It has been a commonly accepted conclusion that the Negro can not withstand the more rigorous climate of the northern states. There are few Negroes in the states bordering our northern boundary, and still fewer in Canada. Climate has been held to impose a barrier to the northward spread of the black man as it does to the distribution of many species of plants and animals. This conclusion has been supported by the fact that until very recently most northern states and cities have had more deaths than births in the Negro race.

Ever since the Civil War we have had an increasing migration of Negroes into the north. At first they did not, as a rule, travel far north, but of late they have been appearing in our northernmost states in rapidly increasing numbers. The demand for labor dur-

[1] The term "colored" as used in our vital statistics includes a few persons of other races besides the Negro, but in the regions considered the proportion of these is so small that no error of moment will be made by disregarding them.

ing the great war drew vast numbers into the industrial plants of our northern cities. Between 1910 and 1920 the Negro population of New York City was increased by 60,758, or 66.3 per cent.; that of Chicago by 65,355, or 148 per cent.; that of Cleveland by 26,003, or 307.8 per cent., and that of Detroit by 35,097, or 611.3 per cent. Since the war, Negro migration slackened, but it still continues to a large but not precisely ascertainable extent. The shortage of labor arising from the restriction of European immigration has created, and will continue to create, a demand for Negro employees which will cause a steady inpouring of black humanity into our northern centers of industry. The Negro bids fair to supply no small part of our laboring population in many kinds of employment. He finds conditions in the north more attractive in several respects than in the south. He usually secures better wages, a superior social status and better educational advantages for his children. Often he has to put up with housing conditions of the worst description, but they are, as a rule, no worse than those he left behind. But his conditions of life in the north are improving. With improved facilities for education, combined with higher wages, his station in life may become quite as favorable as that of the whites in similar employments.

But will he thrive? Formerly the Negro armies have been marching north to their destruction. A study of the balance sheet of births and deaths in any of the states or cities of the north shows that deaths among the Negroes have everywhere been more numerous than births. Pneumonia, tuberculosis, venereal diseases, a high infant mortality and the various ailments resulting from ignorance and improvidence have taken so heavy a toll that even Negro fecundity was unable to compensate for the losses. Recently, however, the situation has begun to take on a new aspect. In several northern states and cities Negro births have become more frequent than Negro deaths. The last two volumes on birth statistics (1924, 1925) show more births than deaths in California, Connecticut, Illinois, Indiana, Maryland, Massachusetts, Michigan, Montana, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, Utah and Washington, whereas in 1915 all these states in the registration area which had any considerable number of Negroes showed, with the exception of Massachusetts, an excess of deaths over births. One has to allow something, of course, for improvements in the registration of births, but the fact that these states are in the registration area indicates that their records had reached a fairly high standard.

Another factor which should be considered is the age composition of the Negro population. Recent migrants to the north include many Negroes in the middle period of life when child-bearing is relatively frequent, and our statistics might therefore give an exaggerated picture of the real fecundity of the group. Fortunately a certain amount of check is supplied by the data which the Bureau of the Census has recently published on the size of families. These data show that in practically all the northern states the total number of children born to each mother who gave birth to a child during the year is greater in the colored than in the native white population, although somewhat less than the number of children of mothers who were foreign born. When we allow for mortality by considering only living children the advantage still lies with the colored family as compared with that of the native-born whites. The same relation is shown when we measure the birth-rate by taking the number of births per thousand women of child-bearing age. The available data agree in pointing to the conclusion that the

AVERAGE NUMBER OF CHILDREN EVER BORN TO WOMEN WHO BECAME MOTHERS IN 1924 BY COLOR AND NATIVITY IN REPRESENTATIVE NORTHERN STATES

	Native Born	Foreign Born	Colored
Registration area	3.0	3.9	3.7
Cities	2.5	3.6	3.1
Rural districts	3.4	4.7	4.0
California	2.4	3.4	3.2
Connecticut	2.6	4.2	3.3
Illinois	2.7	3.6	3.0
Indiana	3.1	4.0	3.4
Iowa	3.0	4.1	3.1
Kansas	3.1	4.6	3.4
Maryland	3.2	4.2	4.0
Michigan	3.0	3.8	3.2
Minnesota	3.1	4.4	3.6
New York	2.6	3.5	2.9
Ohio	2.9	4.0	3.3
Pennsylvania	3.1	4.8	3.2

Negroes are more than holding their own in most places in the north. Up to the period of the great epidemic of influenza the balance sheet of births and deaths was against the northern Negro; during the last four or five years it has been decidedly in his favor.

Northern Negroes are largely inhabitants of cities. The efficient means taken in many northern cities for the promotion of public health have materially increased the Negro's chances of survival. In New York City, whose public health administration is one of the best and whose Negro population is now one of the largest (over 160,000), the death-rate of the Negroes has markedly decreased, while the birth-rate has been rising. The previously very high infant mortality of the Negroes has declined more rapidly than that of the whites. In fact, *it has been nearly cut in half in the short space of a single decade,* and is now at a point lower than the rate for white infants not many years ago. With an improved milk supply, free clinics, opportunities for prenatal care and various other means for promoting the welfare of mother and child, the Negroes of New York City are finding conditions quite favorable for the perpetuation of their kind. The large life insurance companies, such as the Metropolitan, have done much through health education and supplying free nurses to increase the longevity of their colored patrons. The treatment of expectant mothers afflicted with syphilis, which is so common a scourge of the American Negro, has proven effective in the reduction of still-births and abortions, and will doubtless tend to enhance the birth-rate and reduce infant mortality. It is not surprising that New York City was among the first of the cities of the north to show a preponderance of births over deaths in its Negro population.

In connection with the problem of the fate of the northern Negro it is of interest to compare the vital statistics of Negroes in northern and in southern cities. Taking the cities of the northern states in the registration area for births in 1924, we find a surplus of 11,729 births over deaths, whereas in the cities of the six states in this area south of the Ohio and Potomac rivers the excess of births over deaths is only 227. It is true that the northern cities contain a larger number of Negro inhabitants, but less than three times as many (1,603,021 as compared with 644,309), while if we consider their excess of births over deaths they have contributed more than fifty times as many persons to the Negro population. In the cities of South Carolina, Mississippi and Kentucky there were actually more Negro deaths than births.

INFANT MORTALITY RATES (DEATHS PER ONE THOUSAND BIRTHS) OF THE WHITE AND COLORED POPULATION OF NEW YORK CITY, 1915–1924

	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
White	97	92	87	90	79	83	69	73	65	66
Colored	200	169	176	171	145	157	135	117	116	106

If we are not to be misled by the trickiness of vital statistics in interpreting the meaning of these striking facts we must be on our guard against various sources of error. Aside from the incompleteness of registration, especially of births, which is apt to be greater among the Negroes than the whites, there are differences in age composition to which we have referred which have a marked influence on crude birth and death rates. But when urban mortality rates are adjusted for age there is, in general, a higher Negro mortality in southern than in northern cities, indicating that conditions of life are more favorable for the urban Negro in the northern states. For reasons previously given, the increase of the Negro birth-rate in northern cities probably represents a real condition instead of a mere statistical relation. It required some time for the numerous migrants of the war period to become more or less established. The rise of the Negro birth-rate in the north probably reflects the influence of an improving economic status and a better adjustment to a new environment. While it may be too soon to assert that the northern Negroes will continue to increase through their own birth-rate, the conclusion that they can not survive in a higher latitude is hardly warranted by existing facts.

Cityward migration checks the multiplication of blacks as well as whites, but it may well happen that the improvement of our public-health activities will bring about a still greater preponderance of Negro births over deaths in the northern states. Possibly the Negro is destined to form the relatively fecund stratum of our urban population which supplies a large share of our unskilled and partly skilled labor. By nature the Negro is endowed with a physical constitution which is probably not inferior to that of his white compatriot. Although his racial heredity may predispose him to tuberculosis and pneumonia, there is evidence that he is building up a partial immunity to these diseases similar to that acquired by the whites. If he proves successful in adapting himself to these maladies his high mortality may become a temporary episode of his history which may be overcome through education and improved economic conditions. If the Negro is destined to decrease in numbers it will be owing, I believe, more to causes affecting the birth-rate than to any physical inferiority which makes for high mortality.

Other things equal, a low-standard population tends to outbreed a high-standard population. If the north proves to be a field in which the Negro race is capable of expansion through its own birth-rate there is no way to predict the extent of its eventual spread. Hitherto the whites have increased much more rapidly than the Negroes, but we should remember that up to the period of the great war we were receiving annually a large army of immigrants from Europe, and that these immigrants were a very prolific group. The second generation of immigrants, although less prolific than their parents, continued to produce larger families than the native-born Americans of native parentage. Over large areas, especially in the north and east, this latter group has probably not been self-perpetuating. With the drastic restriction of European immigration we may expect a further fall in the birth-rate of the northern whites. Had it not been for our immigrants and their immediate descendants the rate of increase of our white population would have approached much more closely to that of the Negroes. Perhaps the future will see a larger proportion of Negroes in the north than in the south. No one knows. There are too many uncertain factors in the problem to make prediction safe, but the next few years will probably bring us data for making a much better judgment than is possible at the present time.

EXPERIMENTAL DETERMINATION OF THE VELOCITY OF LIGHT[1]

By ALBERT A. MICHELSON, U. S. N.

CONSIDERING the importance of this physical constant as one of the simplest and most accurate means of ascertaining the distance of the sun from the earth, it seems surprising that but three scientists have sought to obtain it experimentally.

These were Foucault, Fizeau and more recently Cornu.

Foucault used the method known as that of "Wheatstone's revolving mirror," the application of which was first suggested by Arago.

Fizeau and Cornu both used another method, known as that of the "toothed wheel."

In Foucault's experiments the distance traversed by the light was 20 meters. The result obtained was 185,200 miles per second. Cornu's stations were about 14 miles apart. The result obtained by him was 186,600 miles, which exceeds the former one by 1,400 miles.

The objection to Foucault's method is that the displacement, a quantity which enters directly in the formula, is very small, and therefore difficult to measure accurately. The objection to Fizeau's is that the time of total disappearance of the light was necessarily uncertain.

The object of the experiments which I have undertaken is to increase the displacement in the first method. This can be done in several ways: 1st, by increasing the speed of the mirror; 2nd, by increasing the distance between the two mirrors; 3rd, by increasing the radius of measurement, *i.e.,* the distance from the revolving mirror to the scale.

In Foucault's experiments the speed of the mirror was 400 turns per second: the radius of measurement was about one mètre, and the distance between the mirrors was about ten (10) mètres. The displacement obtained was about 0·8 milimètre.

In my experiments, the speed of the mirror was but 130 turns per second—but the radius of measurement was from fifteen to thirty feet—and the distance between the mirrors was about 500 feet.

The displacement obtained varied from 0·3 inch, to 0·63 inch, or about twenty times that obtained by Foucault.

With a greater distance between the mirrors, and better apparatus, I expect to obtain a displacement of two or three inches and to measure it to within one thousandth part of an inch.

The following is a description of the apparatus employed in these preliminary experiments.

Fig. 1 represents the plan. The sun's rays are reflected by a heliostat through a slit S, and upon a mirror R, which revolves about a vertical diameter. They are thence reflected to a fixed plane mirror M, upon the surface of which an image of the slit is formed by means of the lens L. The light now retraces its path, and finally forms an image of the slit, which, when the mirror, R, is at rest, coincides exactly with the slit itself. When the mirror revolves slowly, this coincidence is still maintained, but the

[1] Reproduced on the occasion of the fiftieth anniversary of the presentation of this historical paper before the American Association for the Advancement of Science. It was printed in 1878 in the *Proceedings* of the Association. The Michelson Meeting of the Optical Society which convened during the first week of November celebrated this event. An account of this meeting—together with a picture of Dr. Michelson—may be found at the end of this number.

image is perceived by flashes of light at each revolution till they follow each other in such rapid succession as to form a continuous impression. This image is displaced more and more as the revolution becomes more rapid, the displacement being twice as great as the displacement of the mirror, during the time required for the light to travel from *R* to *M* and back again.

It will be observed that the difference between this arrangement and that of Foucault is that the concave mirror is dispensed with, its office being accomplished by the lens and plane mirror; and that this arrangement permits the use of *any* distance between the mirrors.

When the revolving mirror is in the astronomical focus of the lens, the light, reflected from it in directions continually changing as the mirror revolves,

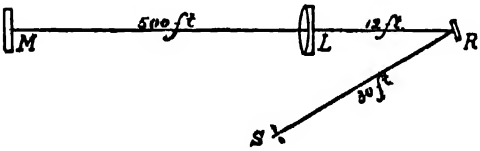


FIG. 1

is, after passing through the lens, always rendered parallel to the axis. Thus, all the light which comes during the part of a revolution represented by the angle subtended by the lens, is collected into a succession of pencils whose axes remain parallel to the axis of the lens; hence the distance between the mirrors may be as great as we please.

It is to be remarked, however, that as this distance is increased, the radius (or distance *R S*, Fig. 1) must be decreased, if we wish to preserve the maximum of light. In practice, it was found unnecessary to place the revolving mirror at the astronomical focus of the lens, and, in fact, this distance was in some cases only one fourth the focal length of the lens.

Other things equal, the greater the diameter and the focal length of the lens, the brighter will be the image.

In these experiments the lens and the fixed mirror were those used in one of the expeditions for observing the transit of Venus. The lens was five inches in diameter and thirty-nine feet focal length. The mirror was tested and found to be almost exactly plane. For these experiments it had to be silvered on the front surface.

The lens being in position, the mirror, which had a slow motion in two planes, was adjusted perpendicular to the line passing through their centres, as follows:

A rough adjustment was made by sighting along a square applied to the mirror, and then an observer, with a telescope placed behind the centre of the lens, saw, reflected in the distant mirror, the image of some adjacent object. By signals the mirror was moved till the observer saw the reflection of his telescope exactly in the centre of the mirror, when the adjustment was complete. This adjustment had to be repeated from day to day.

The revolving mirror was next brought into position, and then the slit placed so as to allow the beam of light, passing through it to fall on the revolving mirror, and at such a distance that the image of the slit was superposed upon the slit itself.

The revolving mirror was a disc of plane glass about one inch in diameter—silvered on one side, and supported by two screws, terminating in needle points, which fitted into two small conical holes in the edge of the disc.

It was driven round by a blast of air from a bellows, which impinged upon one half of the mirror. *t*, *t*, *t*, Fig. 2, represents a section of the tube supplying the air. *R*, *R*, is a section of the glass disc; and *O*, is the axis about which it turns.

This crude piece of apparatus is now supplanted by a turbine wheel, which

insures a steadier and more uniform motion.

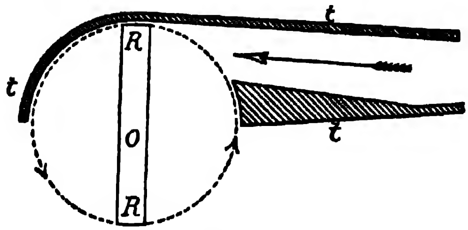


FIG. 2

For keeping the speed constant and for measuring it accurately two devices were used. In the first the light reflected from the revolving mirror fell upon the toothed wheel of a chronograph, which itself was accurately timed after each experiment.

When the time between the passage of two adjacent teeth was the same as the time of one revolution of the mirror, then the wheel appeared stationary, turning slowly forwards or backwards as the mirror revolved too slowly or too rapidly.

In the latter part of the experiments, a tuning-fork, bearing a mirror on one prong, was used. This was kept in vibration by a current of electricity. The fork was placed so that an observer, about to measure the displacement, could also see, in the mirror attached to the fork, an image of the revolving mirror. When both mirrors are at rest, this image is of course similar to the object; but when the fork is set in vibration the image is drawn out into a band.

When, however, the revolving mirror is started and attains the proper speed, the image again assumes its original shape. The fork is afterwards compared with one of König's standards.

The slit and micrometer were connected so as to form but one piece. This piece of apparatus is represented in Fig. 3. *S*, is the slit; *ab*, a piece of plane glass partly silvered. The light, proceeding in the direction *SM*, is re-

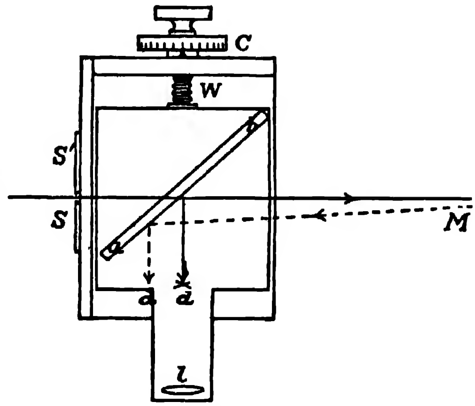


FIG. 3

turned in the contrary direction, and part of it is reflected from the glass *ab*, forming an image of the slit which is made to coincide with the cross-hairs at *d*. When the mirror revolves this image is displaced to *d'*. The slit *S* may then be moved in the direction *SS'* till the *displaced* image coincides with the cross-hairs, and the distance *SS'* accurately read by a screw bearing a divided circle. This method of observing does away with any error which might arise from "parallax" due to inexact focusing.

In these experiments the displacement was so great that the slit moved entirely outside the field of light. To avoid this difficulty, the other parts of the apparatus, viz.: *ab*, the glass mirror, *d*, the cross-hairs, and *l*, the lens for viewing the image—were moved by the screw *w* in the opposite direction past the slit; the distance moved, which is exactly equal to the displacement, is accurately read on the divided circle *c*.

The piece of glass *ab* was partly silvered in order that when the mirror was at rest, the image of the slit would be seen from the unsilvered portion, while the *displaced* image, which is very much fainter, would be seen by reflection from the silvered part.

The annexed table gives the results of ten independent observations, made under difficulties and with apparatus adapted from the material found in the Laboratory of the Naval School:

Their accordance with each other and with the generally accepted result justifies the expectation of obtaining, with proper appliances and under more favorable conditions, the correct result within a few miles; and, I trust, justifies the demand I have made on your time and attention.

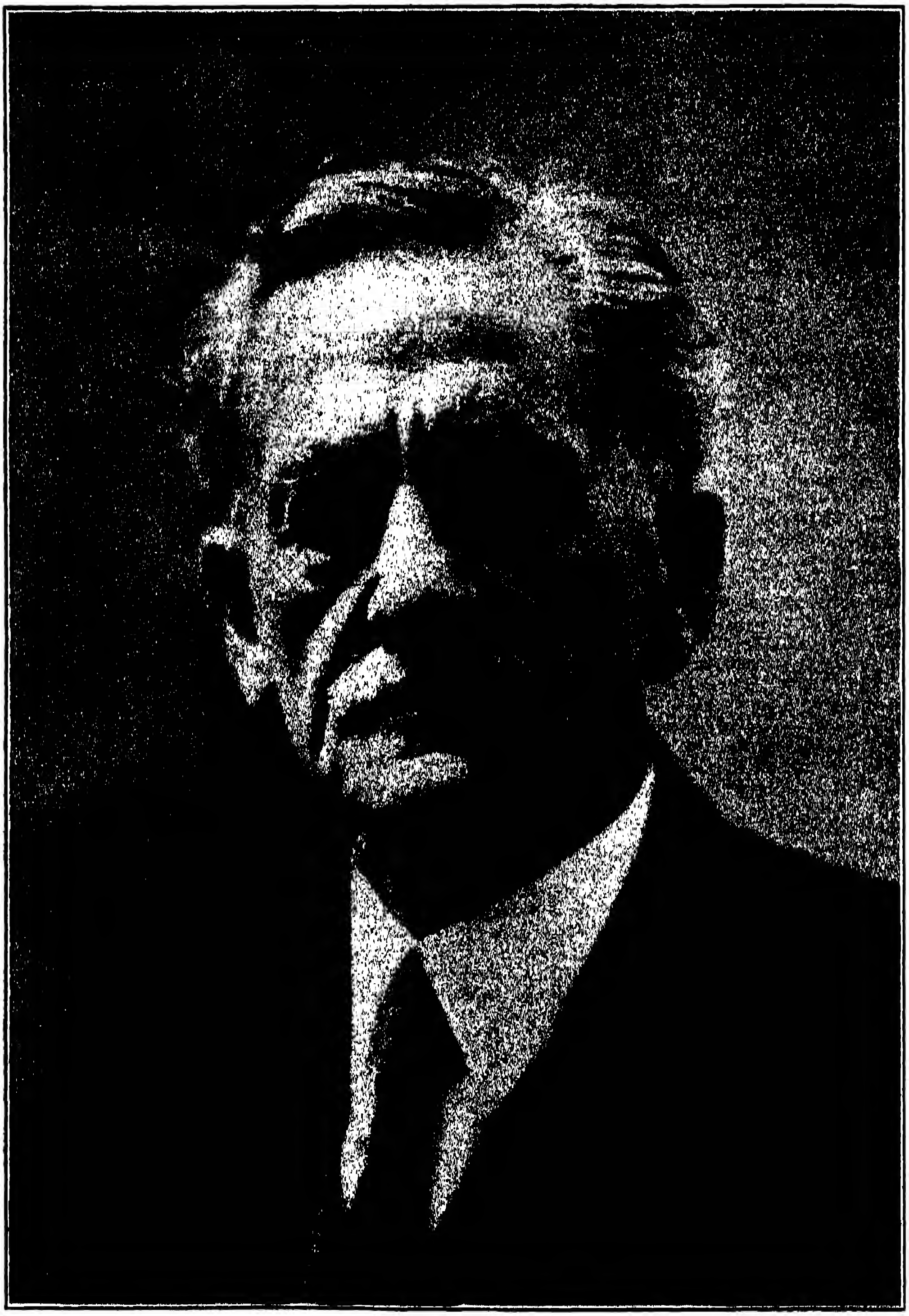
In conclusion, I take this opportunity of tendering thanks to Mr. A. G. Heminway, of New York, for contributing $2,000 for the purpose of carrying out these experiments.

RESULTS OF OBSERVATIONS

Velocity of Light in Air in Miles Per Second
186,730
188,820
186,330
185,330
187,900
184,500
185,000
186,770
185,800
187,900
Mean – 186,508

Formula, $V = \dfrac{4 \pi r n D}{\delta}$

V = velocity of light.
r = radius of measurement.
n = number turns per sec.
D = twice dist. bet. mirrors.
δ = displacement.



ALBERT A. MICHELSON

THE PROGRESS OF SCIENCE

THE MICHELSON MEETING OF THE OPTICAL SOCIETY OF AMERICA

By Hugh G. Boutell

Probably the most notable and interesting meeting which has ever taken place in the lecture room of the National Bureau of Standards was that of the Optical Society of America on the afternoon of November 2, when members of the society, a large percentage of the staff of the Bureau, and as many others as could possibly get within the hall or around the loud-speakers outside gathered to hear Professor Albert A. Michelson present the results of his latest experiment on ether drift, and incidentally to do honor to the dean of American optics. If Professor Michelson experienced any disappointment in getting no indication of ether drift in his latest repetition of the Michelson-Morley experiment it must have been more than offset by the reception which was given him at the "Michelson Meeting" of the Optical Society.

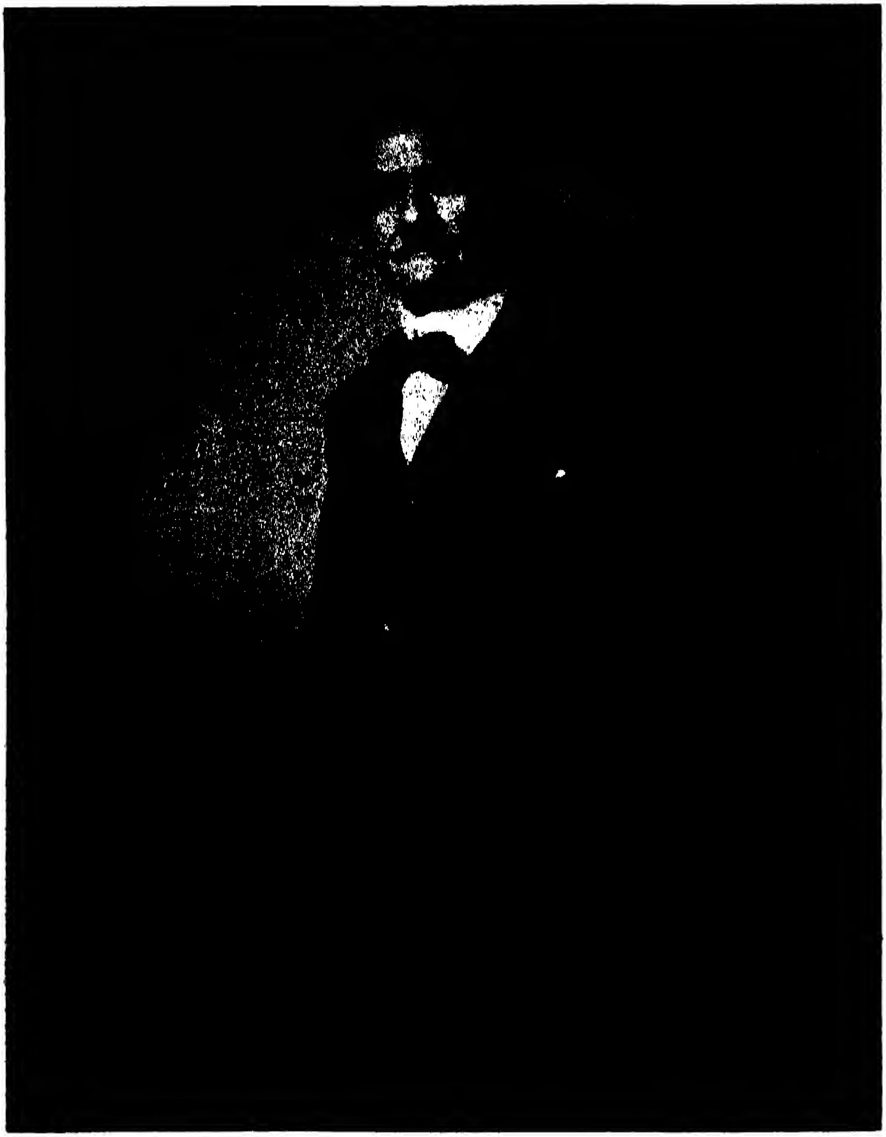
It was peculiarly fitting that when the executive council was planning this thirteenth annual meeting of the society, they should decide to name it "the Michelson Meeting," because it was just 50 years ago that A. A. Michelson, then an ensign at the United States Naval Academy, now the veteran of many victories in the intellectual conquest of nature, published his first contribution to a scientific journal, an item of only a few lines and a single diagram on his now renowned method for measuring the velocity of light (*Silliman's Journal*, Vol. 15, p. 394; May, 1878). The method was described in detail in a paper presented at the meeting of the American Association for the Advancement of Science in August, 1878, which is reprinted from the *Proceedings* in the present issue of The Scientific Monthly.

As Mr. I. G. Priest, the president of the Optical Society, said, it is human custom to celebrate various occasions, birthdays and even deaths; but the Optical Society had chosen this occasion to celebrate the intellectual birthday when the man Michelson was born into the field of work in which he is now the acknowledged leader.

This semi-centennial was distinguished above all else by the happy fact that, after half a century of devotion to research in optics, Professor Michelson himself contributed the outstanding paper on the program—"Results of Repetition of the Michelson-Morley Experiment." After he had narrated briefly the history of this famous experiment, and described his new apparatus, he announced that his recent experiments, in collaboration with Messrs. Pease and Pearson, showed no difference in the velocity of light in various directions of as much as 1/500 of that which should be found if the earth really is drifting through a stationary ether His latest experiment therefore confirms the results of his first attempt to measure the absolute motion of the earth through space in 1887.

Following Professor Michelson's paper, tributes of appreciation and respect were paid to this indefatigable investigator by Professors Lyman, Swann, Richtmyer and Miller.

On the same evening a dinner in honor of Professor Michelson was held at the Cosmos Club. Among the speakers was Dr. C. E. Munroe, of the National Research Council, internationally known authority on explosives, and an intimate friend of Professor Michelson at Annapolis. His references to Professor Michelson's early work and particularly to his many activities and interests out-



Very sincerely yours
A. A. Michelson

—*Courtesy of the Optical Society of America*

side the field of physics, were of the greatest interest. Dr. Munroe took this occasion to return to Professor Michelson an oil painting of a plate of apples which the latter had executed when he was considering the possibility of supplementing his skill by a knowledge of painting. The picture was a creditable performance and Dr. Munroe suggested that it be used as the nucleus of a permanent collection of material associated with Professor Michelson's early work.

Professor Michelson's address at this dinner was also rich in reminiscences of his younger days, among them being the time when one of the instructors at the Naval Academy took him to task for his lack of interest in subjects other than mathematics, chemistry and physics and warned him to drop this "scientific stuff." He attributed his interest in what later became his life's work to an assignment by Admiral Sampson to deliver a lecture on the velocity of light. It was while developing an apparatus to be used for demonstration purposes in this lecture that he started to make actual measurements of the speed of light on his own account.

The dinner was likewise notable as the occasion selected by Dr. Herbert E. Ives for presentation to the Optical Society of America of the Frederic Ives medal which Dr. Ives has endowed in honor of his father, distinguished for his pioneer contributions to color photography, photoengraving, three-color process printing and other branches of applied optics. The medal will be awarded biennially by the society "for distinguished work in optics."

Thirty-nine papers were presented on many diverse subjects in optics. An unusual feature was the presentation, for the first time in the United States, of the remarkable motion picture film made by Professor W. H. Wright at the Lick Observatory, illustrating the rotation of the planet Jupiter. Not only was every surface feature presented on the screen, as the great sphere turned on its axis, but a transit of one of the satellites and its shadow was visible as light and dark spots crossing the disk. Pictures in ultra-violet and infra-red light gave very different aspects, showing the greater penetration of the red light through the planet's atmosphere.

Another feature which excited great interest and admiration was the demonstration of Technicolor motion pictures by Dr. L. T. Troland.

In connection with the meeting an extensive exhibit of optical instruments and related material was arranged by a special committee of the society and the Bureau of Standards. The latest designs of optical equipment were shown by prominent manufacturers in this field.

The development of the microscope from 1665 to recent times was shown in a special exhibit of original instruments and reproductions kindly loaned for the occasion by the Medical Museum of the United States Army.

An interesting collection of ancient and modern books on optics (including most of those containing Professor Michelson's contributions), photographs and engravings was shown by the Smithsonian Division of the Library of Congress.

The book registration for the meeting was about 675 and it is estimated that probably one thousand persons visited the exhibition or attended some session of the meeting. About 400 persons heard Professor Michelson's paper and probably as many more were turned away from the overcrowded lecture hall. Over 200 persons attended the dinner, and more would have come had there been places for them. In order to satisfy the demands of those who wished to see the motion pictures of the planet and the Technicolor motion pictures, these were all shown three times and were seen by about one thousand persons.

THE MICHELSON–MORLEY ETHER DRIFT EXPERIMENT

When Professor A. A. Michelson, of the University of Chicago, announced at the meeting of the American Optical Society the latest results of his work on ether drift, he wrote the latest chapter in a history which he began, and in which the theory of relativity that made famous the name of Einstein plays an important part.

According to a review of the work prepared by *Science Service* it was in 1887 that Professor Michelson, then at the Case School of Applied Science in Cleveland, collaborated with his colleague, Professor E. W. Morley, in performing the now classical Michelson-Morley experiment. Up to that time scientists were generally agreed in supposing that light waves traveled through a queer medium which pervaded all space, and which was called the ether. If the ether was in all space, then it should be possible to detect the earth's motion through it. The earth travels around in its orbit at a speed of about 20 miles per second. If a beam of light is divided into two parts then sent in directions at right angles to each other, reflected from two mirrors back and recombined, light and dark bands may appear. These are due to the light waves getting tangled up, and interfering, and so are called interference bands.

If one beam of light has to travel a little longer than the other, the bands are moved and so the method affords a very delicate method of measuring minute displacements. In one form this interferometer has proved a valuable scientific measuring instrument. Motion through an ether would produce the same effect as a lengthening of one of the beams, and so would theoretically cause a shift in the fringes, depending on the direction of the light paths with respect to the earth's motion. Professor Michelson and Professor Morley tried the experiment, but found an effect far less than that expected. So small was it that they attributed it to unavoidable errors. Other experiments were later devised to show the same effect, but none of them gave any evidence of the earth's drifting through the ether.

Then physicists began to search around for some explanation of why this effect did not occur. Professor H. A. Lorentz, of Holland, proposed what is now termed the Lorentz-Fitzgerald contraction. This was that motion through space produces an actual shrinkage of physical objects, which would just balance the effect sought for. As all measuring sticks would be similarly affected, it would be impossible to detect this contraction. Finally, as a further development of these ideas, Einstein proposed his preliminary theory of relativity in 1905, followed by his general theory in 1915.

In the ten years after the publication of Einstein's paper, the three "proofs" of the theory that he suggested were all successful. One was the explanation of the strange behavior of the orbit of the planet Mercury. Another was the bending of light waves as they passed near the sun, shown by observations made during solar eclipses. The third was the shift in the lines of the sun's spectrum when compared with spectra of light from terrestrial sources. Accordingly, the relativity theory was placed on just about as firm a foundation as a theory could be.

But a difficulty appeared in 1925. Dr. Dayton C. Miller, professor of physics at the Case School of Applied Science, where Michelson had first performed his experiment, tried it again. Miller obtained small effects, less than had originally been expected, but apparently definite and consistent. They seemed to show a motion of the earth towards part of the sky near the constellation of Lyra. As astronomers actually

recognize the existence of such a motion, the results seemed rather convincing.

Though efforts were made at the time to get Professor Michelson to comment on this result, surprising to science because it did show an effect, he said nothing. However, he was not satisfied with the situation so he set out to repeat the experiment himself. In the meantime other scientists tried the experiment, one in Germany even making observations from a balloon, but none confirmed Professor Miller's results. All gave the same negative result that had been obtained before.

No one questioned the accuracy of the original Michelson-Morley experiment. Professor Miller pointed out that Michelson had obtained a slight effect, attributed to experimental errors, and that it was genuine. Still Professor Michelson said nothing, but continued his preparations to repeat the experiment on a far more accurate scale than ever before. If he still obtained the small effect, it would be obvious that it was real, but if it were eliminated or greatly reduced, then it would be apparent that in originally attributing it to experimental errors he had been justified.

The apparatus was set up in one of the buildings of the Mt. Wilson Observatory in Pasadena, California. The steel plate on which the 100-inch mirror of the observatory's great reflecting telescope had been ground was used to support the apparatus. In his experiment originally, and as repeated by Miller, the observer had to walk around it as it turned, at the same time making the observations. The new apparatus was so arranged that the observer made his observations from the room above through an eyepiece directly above the center of the instrument. Though forced to spend several sojourns in hospitals, Professor Michelson was assisted by two members of the observatory staff, Francis G. Pease and Fred Pearson, and the work was carried out. Last September he went to Pasadena to make the final series of observations.

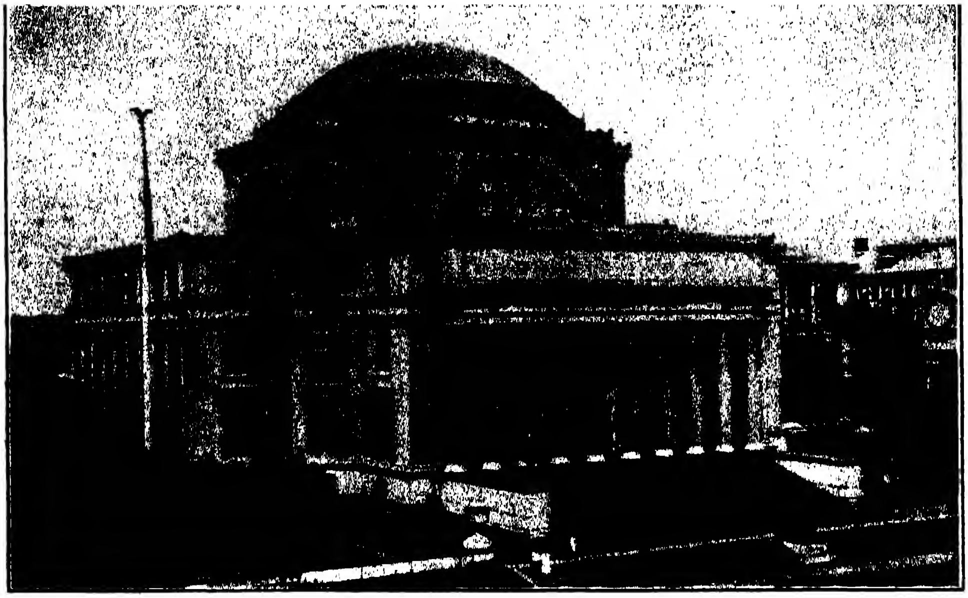
Now he has announced his results. With the motion of the earth of approximately 20 miles per second, the theoretical displacement due to drift through the ether should be about equal to one half the width of the bands. "I found no shift as large as a thousandth of the width of a band," Professor Michelson said.

As the very slight observed shift is about a tenth of what he got in 1887, it now seems certain that it is due to experimental errors, and that the larger effect obtained by Professor Miller was due to some other cause. Just what this cause was, he does not suggest, and neither does Professor Miller.

THE NEW YORK MEETING OF THE AMERICAN ASSOCIATION

The American Association for the Advancement of Science and the Associated Scientific Societies will meet in New York City from December 27 to January 2. It is one of the greater convocation week meetings held at intervals of four years successively in Washington, New York and Chicago. The twelve years since the association last met in New York have been a significant period in the history of the nation and in the progress of science, and we may expect the approaching meeting to exceed all others in the work that it will accomplish for the advancement of research and the wider diffusion of scientific interest.

Dr. Henry Fairfield Osborn, president of the association, will be able to welcome it to the American Museum of Natural History, which under his direction has become one of the great scientific institutions of the world. The meetings of the association, of its fifteen



THE LIBRARY OF COLUMBIA UNIVERSITY

sections, and of the forty-four associated societies will be held mainly at Columbia University and at the American Museum, but some sixty scientific and educational institutions of the city are cooperating in the arrangements.

The opening meeting will be on Thursday evening in the American Museum, when, after brief addresses of welcome Professor Charles P. Berkey, of Columbia University, will speak on recent researches on the geology of Mongolia. There will follow a general reception and the exhibition halls of the museum will be open, several new exhibits being on view for the first time.

On Monday evening Professor A. A. Noyes, of the California Institute of Technology, retiring president of the association, will give the annual address on "The Story of the Elements." Among evening addresses in the museum will be the Sigma Xi lecture by Professor Arthur H. Compton, of the University of Chicago, recently awarded one of the Nobel Prizes, whose subject is "What is Light?" Professor W. M. Wheeler, of Harvard University, will lecture on new tendencies in biological theory. Professor Harlow Shapley, director of the Harvard College Observatory, will speak on "Galaxies of Galaxies." After each of these addresses there will be a reception and the corresponding halls of the museum will be open throughout the evening.

Among the large number of general addresses may be noted the Josiah Willard Gibbs lecture by Professor G. H. Hardy, of the University of Oxford, entitled "An Introduction to the Theory of Numbers"; one by Professor Franz Boas, of Columbia University, on "Immigration of Asiatic Races and Cultures to North America," and the exhibition of a Canti film showing in motion pictures the behavior of tissue cells, by Professor Charles A. Kofoid, of the University of California.

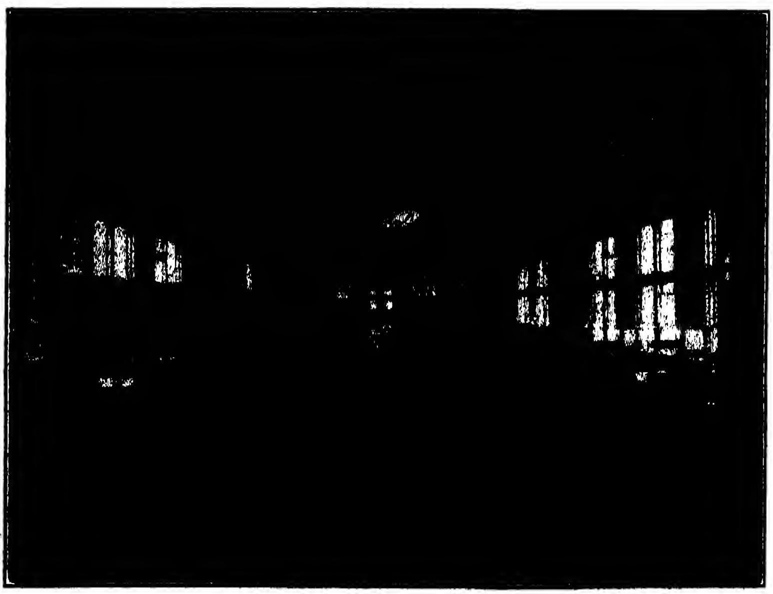
Each of the sections and societies meeting during the week has its own program which in many cases includes general addresses, joint meetings and symposia that are of interest to those

—*From the American Museum of Natural History*

THE AMERICAN MUSEUM OF NATURAL HISTORY

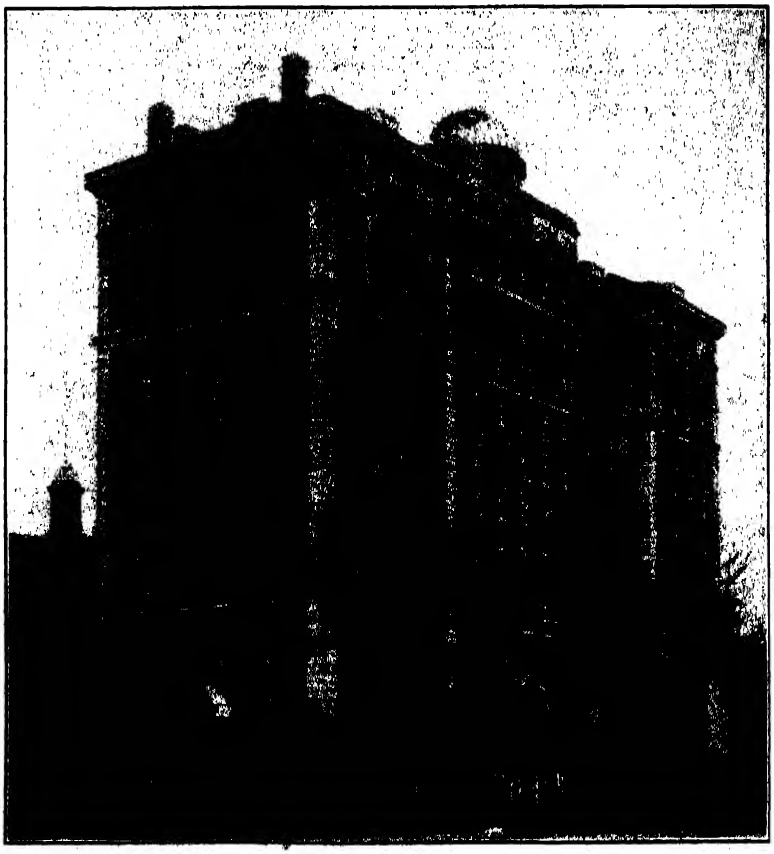
who are not specialists. A list of these would fill an entire issue of this magazine; the full program will extend to three hundred pages.

The groups of scientific men will have their dinners, smokers and other social events. The scientific exhibit gives not only an opportunity to learn about recent advances, but also provides a place where scientific men can meet one another. This year there is an intervening Sunday which gives opportunity for a philharmonic symphony concert in Carnegie Hall, a reception at the Metropolitan Museum of Art, and day excursions to the New York Botanical Garden, the Aquarium, the Medical Center of Columbia University and the Presbyterian Hospital, the Cornell University Medical College, the Rockefeller Institute for Medical Research, the Boyce Thompson Institute for Plant Research and other scientific and educational institutions.



—*From the American Museum of Natural History*

THE MORGAN HALL OF GEMS, AMERICAN MUSEUM OF NATURAL HISTORY



THE NEW PHYSICS BUILDING OF COLUMBIA UNIVERSITY

The local arrangements for the meeting are in the hands of an executive committee, of which Professor George B. Pegram, dean of the School of Applied Science of Columbia University, is chairman, Professor M. I. Pupin, president of the association four years ago, honorary chairman, and Professor Sam F. Trelease, secretary. There are numerous special committees on which the scientific men and the scientific institutions of the city are fully represented. The association is especially fortunate in the circumstance that Professor Osborn, its president, has been able to take a leading part in the arrangements.

The issue of *Science* for November 30 contains the preliminary program, edited by Professor Burton E. Livingston, with full details concerning hotel headquarters, transportation, places of meeting and the more general features of the program. A copy of this issue of *Science* can be obtained without charge from the Permanent Secretary of the American Association for the Advancement of Science, Smithsonian Institution Building, Washington, D. C.

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

Agassiz, Louis Jean Rudolphe, Portrait, 189; Survey of Life of, H. A. WARREN, 355
ALLARD, H. A., Musical Expression among Insects, 81
ALLEN, G. M., Whales and Whaling, 340
American Association, New York Meeting of, 571
Amundsen, Roald, Portrait, 383
ANDREWS, W. S., "Hypon"—A Hypothetical Element, 535
Animal, Wild, The Most Interesting in America, E. R. WARREN, 33
Arnold Arboretum of Harvard University, 95
Arsenic, A Substitute for, S. MARCOVITCH, 459
Atmosphere, High, of the Earth, E. O. HULBURT, 134
Australia, A Glimpse of, A. C. LAWSON, 244

BANGHAM, R. V., Parasites of Black Bass, 267
BARBOUR, T., The Largest Reptiles, 337
BARNES, W. C., Tularemia, 463
BARRETT, O. W., Shark Fishing, 125
BENEDICT, F. G., Basal Metabolism, 5
BENNETT, H. H., Heritage of the Nation, 97
Bio-ecology of Forest and Range, W. P. TAYLOR and W. G. MCGINNIES, 177
Biology, Mathematics in, J. A. HARRIS, 141
BLANCHARD, W. O., Malaria as a Factor in Italian Environment, 172
Botanizing on Barro Colorado Island, Panama, L. A. KENOYER, 322
BOWEN, E., Ships, 57; Over-seas Carrying Trade, 153
BRAGG, SIR W., Photoelectricity, 522
BROOKS, B. T., Research, 410
BROWN, R. H., The San Luis Valley, 492
Butter, the Keeping of, O. RAHN, 206

CAJORI, F., Sir Isaac Newton on Gravitation, 47
Carrying Trade, Over-seas, E. BOWEN, 153
LE CHATELIER, H. M., The Formation of the Elite, 212
Chemistry, The Institute of, 473
CLARKE, B. L., Conveying Ideas, 545
Comstock, J. H. and A. B., Portraits, 377
Coral Reefs, Formation of, W. M. DAVIS, 289
Corn Borer and America's Corn Crop, W. H. LARRIMER, 424
CORNISH, V., The Preservation of Scenic Beauty in Town and Country, 349
CRIST, J. W., and M. DYE, Greenness and Vitamin A in Plant Tissues, 166
CURTISS, L. F., Counting Atoms and Electrons, 398
CUSHMAN, J. A., Fossils, 346

DANFORTH, R. E., Human Evolution, 158
DAVENPORT, C. B., Race Crossing, 225
DAVIS, W. M., Formation of Coral Reefs, 289

Educational Trobrianders and the Professorial Illusion, J. M. FLETCHER, 446
Electron Emission from Metals and Crystal Structure, H. E. FARNSWORTH, 138
Electrons and Atoms, Counting, L. F. CURTISS, 398
Elite, The Formation of, H. M. LE CHATELIER, 212
ELLIS, SIR W., Engineering and Civilization, 434
Entomology, International Congress of, 375
Evolution, Human, R. E. DANFORTH, 158; C. G. ROGERS, 506
Exploration, of the Arctic Regions by Means of the Airship, 285; Scientific, G. F. FERRIS, 537

Fame, Hall of, 190
FARNSWORTH, H. E., Crystal Structure and Electron Emission from Metals, 138
FERNALD, H. T., Insects, the People and the State, 193
FERRIS, G. F., Scientific Exploration, 537
Fishery Investigations in Lake Erie, E. HIGGINS, 301
FLETCHER, J. M., Educational Trobrianders and the Professorial Illusion, 446
Food Prejudices, C. W. TOWNSEND, 65
Forbes, Stephen A., Portrait, 379
Forest Production, A. B. RECKNAGEL, 367
Fossils, J. A. CUSHMAN, 346
Francis, Edward, Portrait, 465
FULTON, B. B., Sound Perception by Insects, 552

Geology, Humanizing, C. N. GOULD, 416
Gobies of the Gulf of Guinea, A. S. PEARSE, 239
GOULD, C. N., Humanizing Geology, 416
Gravitation, Logic of, H. LANZ, 530

HAMMETT, F. S., Heredity Concepts of the Ancient Hindus, 452
HANCE, R. T., Hereditary Constitution and X-Rays, 264
HARRIS, J. A., Mathematics in Biology, 141
Heredity Concepts of the Ancient Hindus, F. S. HAMMETT, 452
Heritage of the Nation, H. H. BENNETT, 97
HIGGINS, E., Cooperative Fishery Investigations in Lake Erie, 301
Holiday, Scientific, A. W. MEYER, 542
Holland, W. J., Portrait, 378
HOLMES, S. J., Will the Negro survive in the North? 557
HULBURT, E. O., The High Atmosphere of the Earth, 134
Hunter, John, 183, Portrait, 184

Ideas, Conveying, B. L. CLARKE, 545
INGALLS, N. W., On Righthandedness, 307

Insects, and Birds, W. L. McAtee, 77; Musical Expression among, H. A. Allard, 81; the People and the State, H. T. Fernald, 193; of the Household, C. W. Johnson, 343; Sound Perception by, B. B. Fulton, 552
Irvine, Sir James, Portrait, 475

Johnson, C. W., Insects of the Household, 343

Kenoyer, L. A., Botanizing on Barro Colorado Island, Panama, 322
Koller, L. R., The Radioactive Elements, 54
Koppányi, T., Transplantation of Organs, 502

Lamme, Benjamin G., Medal, Award, 284
Lanz, H., Logic of Gravitation, 530
Larrimer, W. H., America's Corn Crop and the Corn Borer, 424
Laufer, B., The Prehistory of Television, 455
Lawson, A. C., A Glimpse of Australia, 244
Little, Arthur D., Portrait, 381

McAtee, W. L., Birds and Insects, 77
Magic, Agricultural, G. M. Ziegler, 69
Malaria as a Factor in Italian Environment, W. O. Blanchard, 172
Marcovitch, S., A Substitute for Arsenic, 459
Marine Biological Laboratory, 186
Maya Exploration, 479
Medical Center of New York City, 470
Metabolism, Basal, F. G. Benedict, 5
Meyer, A. W., That Scientific Holiday, 542
Michelson Meeting of the Optical Society of America, 567; Morley Experiment, 570
Miles, W. R., Visual Illusions of Motion, 481
Morse, Samuel Finley Breese, Portrait, 191

Nansen, Fridtjof, Portrait, 285
Nebular Hypothesis, C. C. Wylie, 260
Negro Survival in the North, S. J. Holmes, 557
Newton, Sir Isaac, on Gravitation, F. Cajori, 47
Noguchi, Hideyo, 89, Portrait, 90

Parasites of Black Bass, R. V. Bangham, 267
Pearse, A. S., The Gobies of the Gulf of Guinea, 230
Perrine, J. O., Being a Scientist, 28
Photoelectricity, Sir W. Bragg, 522
Physiology of the Ductless Glands, N. B. Taylor, 385
Pine, Longleaf, Root System of, 384
Plant Tissue, Greenness and Vitamin A in, J. W. Crist and M. Dye, 166

Progress of Science, The, 89, 183, 281, 375, 470, 566

Race Crossing, C. B. Davenport, 225
Radio, Natural History by, 337
Radioactive Elements, The, L. R. Koller, 54
Rahn, O., Why does Butter keep?, 206
Recknagel, A. B., Forest Production, 367
Reptiles, The Largest, T. Barbour, 337
Research, B. T. Brooks, 410
Righthandedness, N. W. Ingalls, 307
Rogers, C. G., Evolution, 506

San Luis Valley, R. H. Brown, 492
Scenic Beauty, The Preservation of, in Town and Country, V. Cornish, 349
Scientist, Being a, J. O. Perrine, 28
Searles, P. J., A Valuable Tree, 271
Shark Fishing, O. W. Barrett, 125
Ships, E. Bowen, 57
Smith, A. C., Mud-Volcanoes of Turbaco, 42
Smith, Edgar Fahs, 93, Portrait, 92; Memorial Collection, 281
Stellar Energy, a Possible Source of, W. S. Andrews, 535
Swain, George Fillmore, Portrait, 284

Taylor, N. B., The Physiology of the Ductless Glands, 385
Taylor, W. P., and W. G. McGinnies, The Bio-ecology of Forest and Range, 177
Television, The Prehistory of, B. Laufer, 455
Townsend, C. W., Food Prejudices, 65
Transplantation of Organs, T. Koppányi, 502
Tree, A Valuable, P. J. Searles, 271
Tularemia, or Rabbit Fever, W. C. Barnes, 463

Ultra-sound Waves in Biology, 476

Visual Illusions of Motion, W. R. Miles, 481
Volcanoes, Mud-, A. C. Smith, 42

Warren, E. R., The Most Interesting Wild Animal in America, 33
Warren, H. A., Louis Agassiz, 355
Whales and Whaling, G. M. Allen, 340
Wylie, C. C., The Nebular Hypothesis, 260

X-Rays, and Hereditary Constitution, R. T. Hance, 264; Biological Effects of, 382

Ziegler, G. M., Agricultural Magic, 69